

A WORKBOOK  
FOR  
POLLUTION PREVENTION  
BY  
SOURCE REDUCTION  
IN  
TEXTILE WET PROCESSING

by  
BRENT SMITH

October 1988

## PREFACE

This workbook is intended to present some pertinent ideas for waste and waste source reduction in textile wet processing. Some of these ideas are not new, and in fact many have been previously published. References are not individually cited, but are listed in the bibliography. Additional information can be obtained from the author or from the Pollution Prevention Pays Program.

## ACKNOWLEDGEMENT

This document was produced under a grant from the Pollution Prevention Pays Program of the North Carolina Division of Environmental Management. Also, I wish to express my thanks to the workshop steering committee for helpful suggestions in the preparation of this document.

They were:

Charles Brooks

Doug Finan

Gary Hunt

Joan Koonce

Lou Kravitz

Sam Moore

Mike Scott

Cliff Seastrunk

Bill Walsh

Finally, I wish to thank my colleagues in the textile chemistry program at North Carolina State for their helpful suggestions and to Nelda Pryse who prepared the manuscript. The errors which remain are entirely my own.

# CONTENTS

	Page
I General Information .....	1
I.1 Purpose and Scope .....	1
I.2 The Concept of Source Reduction .....	2
I.3 General Techniques for Source Reduction .....	3
I.4 Waste Characteristics - General .....	5
I.5 Chemical Substitutions .....	8
I.6 Process Modifications and Alternatives .....	16
II Chemical Audit .....	41
II.1 Chemical Specialities .....	41
II.2 Prescreening .....	42
II.3 Quality Control of Shipments .....	43
II.4 Case Histories .....	44
II.5 Chemical Commodities .....	45
II.6 Audit Procedures .....	47
III Mechanical Audit .....	49
III.2 Housekeeping .....	49
III.2 Mechanical Audit .....	49
III.3 New Equipment .....	52
IV Case Histories .....	56
IV.1 R e x h a m .....	56
IV.2 Thiele-Engdahl .....	56
IV.3 United Piece Dye .....	57
IV.4 Celanese .....	57
IV.5 American Enka .....	58
IV.6 Ellen Knitting Mills .....	58
V Conclusion .....	60
VI Appendix.. .....	61
VI.1 References .....	61
VI.2 Index .....	64
VI.3 Glossary .....	67

# **PART I - GENERAL/INFORMATION**

## **I.1 Purpose and this Handbook**

This document is intended to provide textile wet processors with useful information for reducing waste (air, water and solid/hazardous) through material substitution, process modification, inventory control, better management techniques, recovery, and reuse. Several types of wastes will be covered, with emphasis on four specific problem areas.

The first problem area is hard-to-treat wastes, i.e. wastes which are persistent or resistant to normal treatment. For textiles, these wastes include color, metals, phosphates, phenols, and certain organic materials, especially surfactants, which resist biodegradation. Because of the extremely expensive and difficult procedures involved in removing these via wastewater treatment, source reduction is an economical and attractive alternative to treatment.

A second major opportunity is source reduction of waste which becomes widely dispersed when it is discharged. Wastes from many textile processes can be captured or reduced easily by process modifications at the source, but once discharged they tend to become widely dispersed and hard to treat. Machinery design, chemical substitution, procedural remedies or other, primary control measures can often accomplish better results at lower cost than treatment. In addition, reclaimed waste in concentrated form (i.e. not dispersed) usually has its highest potential commercial reuse value.

The third type of waste for which source reduction is viable includes offensive or hazardous wastes, especially materials of high aquatic toxicity. For textiles, these include metals, various types of organic materials and surfactants. In many instances, chemical substitutions can effectively reduce production of undesirable process by-products. Frequently, treatment of these hazardous or toxic process wastes leads to undesirable waste treatment solids, for example, metal bearing sludges.

The final problem area is large volume wastes. These can sometimes be reduced by process modification or chemical substitution, or reused either on-site or off-site.

Each of the above types of waste may originate from a variety of textile operations. The purpose of this document is to review reduction/conservation strategies, process modifications, chemical substitutions and reclamation/reuse techniques which reduce the sources of these wastes in textile wet processing, including

- preparation,
- dyeing,
- printing,
- finishing, and
- other sources.

Case histories, in-plant techniques, and actual production experiences will be presented which demonstrate ways to reduce waste at the source. These reductions generally result in economic gains for the processor as a separate benefit from the waste reduction, as well as providing improved compliance with permits and/or pretreatment specifications for POTW's.

## **I.2 The Concept of Source Reduction**

Many treatment systems simply remove an undesirable process waste or by-product from one media and capture it in another. For example, scrubbers on smokestacks remove undesirable combustion products by dissolving them in water. Another example is the biodegradation of chemical waste in textile wastewater, which produces waste sludge (a solid waste). These solids must be disposed and traditional landfilling of sludge has an associated potential for groundwater contamination. Treatment strategies tend to create a chain of waste products which leads to expense and liability which can be perpetuated through many layers of treatment.

An important alternative to treatment is source reduction. This concept looks to the textile wet process itself to determine what changes can be made to reduce waste at its source. This document deals in detail with source reduction strategies, keeping in mind the four main types; hard to treat, highly dispersible, offensive/hazardous/toxic, and high volume wastes cited previously. Source reduction techniques are drawing more and more attention in textiles and other industries across North Carolina and, indeed, the entire country.

Source reduction results in important economic benefits for manufacturers in several ways:

- decreased liability for waste,
- decreased loss of materials and energy as waste products, i.e. more profits,
- decreased waste collection costs,
- decreased handling and treatment costs, and
- potential recycle and recovery value of waste.

Source reductions are usually accomplished by several different techniques:

- raw material control,
- conservation/optimization of chemicals,
- chemical substitutions,
- process modification,
- equipment modification,
- maintenance procedures,
- housekeeping,
- waste recovery (for reuse/recycle), and
- segregation.

Using a combination of the above techniques has produced annual savings of hundreds of thousands of dollars in documented cases. In fact, case histories for 39 firms were reviewed in a report by Pollution Prevention Pays in January 1986, showing an annual savings of over \$12 million. Due to rising costs, these savings will increase as time passes, whereas losses and costs of waste treatment will produce an ever increasing economic disadvantage to processors.

### **I.3 General Techniques for Source Reduction**

In the following sections, specific applications of some general techniques will be presented.

#### **Raw Material Control**

Raw materials coming into a textile process generally include water, substrate (Yarn, fiber, fabric), process chemicals, and dyes. Control can be exercised both by prescreening and by testing shipments as they are received. These precautions provide many important benefits, not the least of which are reduction of off-quality goods, lower reworks, and improved product consistency. Each of these increases manufacturers' profits as well as reduces waste associated with reworks and remakes.

#### **Conservation/Optimization of Chemicals**

It is not unusual to find dyeing and other procedures in textile wet processing which use excessive amounts of chemicals or unnecessary chemicals. Sometimes chemicals are added to procedures to counteract the harmful side effects of other chemicals. For example, defoamer is frequently added to reduce foaming caused by other chemical specialties. In many cases, it is more judicious to adjust, substitute, or to remove offending chemicals from a process than to add more chemicals to offset undesired side effects. Such conservative use of chemicals can significantly reduce waste loads and processing costs.

A good example of chemical specialty misuse is frequently seen with chemical specialty leveling agents and retarders. These are used with a wide variety of dye types (e.g. acid, basic, direct, disperse) to insure even and level dye exhaustion on to the substrate. In most cases, the same level exhaust can be obtained by proper temperature control. However, the use of chemical specialty retarders and levelers usually results in lower ultimate dyebath exhaustion. This means more color in the wastewater, and color is one of the most difficult textile related pollutants to remove from wastewater. Thus the dyer should attempt to maximize dye exhaustion in order to reduce color in the effluent. This also pays large economic dividends by

- providing maximum consistency of shade repeats, and
- minimizing dye use, which results in immediate dollar savings in dye cost.

Another conservation measure is to save unused portions of chemical mixes. Frequently, batch dumps account for a major portion of a processor's waste load.

#### **Chemical Substitutions**

Textile processing is, in general, both chemical intensive and water intensive. Total chemical use can be 10% to over 100% of the weight of the goods. Water use typically varies from 10 to 45 gallons per pound of fabric. Preparation, dyeing, printing, and finishing techniques and equipment vary widely in their chemical and water demands.

For example, cotton can be printed or dyed with direct, fiber reactive, vat, sulfur, naphthol (azoic), mordant or pigment dyes. Each class produces waste of vastly differing quantities and characteristics. For example, pigments use acrylic binders which, if discharged, cause high total suspended solids (TSS) levels. Pigments also frequently contain metals. Vat and sulfur dyes require Redox (reduction/oxidation) agents for application. The choice of a particular Redox chemical can have major effects on the waste's metal content, especially chrome and zinc. Fiber reactive dyes require large amounts of alkali to ionize cellulose so it can react with the dye by nucleophilic substitution. Direct dyes use 90% less salt and alkali; no Redox chemicals (except for repair work) and no metals (except for a few specific direct dyes which contain copper). But direct dyes generally are applied by exhaust methods which tend to discard large percentages (up to 15%) of the color. This choice can lead to color effluent problems. Mordant dyes require pretreatment of the cotton with metals which can lead to metallic contamination of wastewater. Thus the choice of a dye/print system for cotton has a profound impact on the waste characteristics and

quantities produced. This is even further complicated by the wide variety of processing equipment, both continuous and batch, which is available for dyeing.

### **Process Modifications**

Chemical application methods (e.g. process parameters such as time, temperature, wet pickup/liquor ratio, and machine speed) can often have substantial effects on waste loads resulting from a process. For example, fiber reactive dyes can be applied from batch dyeing equipment with an amount of salt on the order of the weight of the goods -- thousands of pounds per day for a typical dyehouse. Alternatively, pad batch dyeing uses no salt at all for the same fiber reactive dyes and same shade on the same fabric. (This technique will be discussed in detail later in this document.) The manner of application of chemicals to substrate is clearly an important factor.

### **Equipment Modification**

In many cases, modifying equipment can provide source reduction such as reducing "drag out" or reducing liquor to goods ratio. Reduced liquor to goods ratio results in less water use and thus less alkali or acid required for pH adjustments, less stabilizer, lubricants, etc. Recycling waste streams within a process can also be effective. Examples such as reusing once through non-contact cooling water and counter current washing are discussed in other parts of this document (see Section 1.6.1).

### **Maintenance**

Equipment maintenance is important in several ways. First, properly maintained equipment produces good work, less reworks, and less off quality materials. Second, spillage, leaks, and other processing bath losses can contribute significantly to waste loads. In addition, the methods and chemicals used for maintenance - particularly machine cleaners, solvents, degreasers, cutting oils and lubricating oils (especially knitting oils) - can contribute greatly to waste loads.

### **Housekeeping**

Although they may seem almost trivial, chemicals which are spilled, dumped, or leaked into drains can be a significant factor. Control measures such as proper clean-up practices (especially capturing offensive wastes such as print paste in "dry" or concentrated form) for drums, tanks, and print screens can make significant source reductions. Keeping waste out of the drains reduces waste loadings.

### **Waste Recovery- Reuse/recycle**

Many wastes have salvage value. This is true both for internal on-site reuse as well as external off-site use. By reusing waste as a raw material, not only is the value of the raw material saved, but less volume of waste has to be treated. Specific examples of this will be reviewed in this document, including dyebath reuse and counter current washing.

### **S e g r e g a t i o n**

There are several reasons that segregation of wastes is desirable:

1. Specific treatments, such as neutralization of acid/alkaline and oxidation/reduction wastes are more effective prior to mixing.
2. Recovery/reuse systems generally are more effective when the waste stream is most concentrated.
3. Mixing hazardous and non-hazardous (or hard to treat and easily treatable) wastes can create unnecessarily large volumes of hazardous (or hard to treat) wastes. Specific examples will be reviewed in other parts of this document.

The above general techniques will be reviewed in following sections with site-specific case histories and suggestions for implementation.

## I.4 Waste Characteristics - General

As described in Section 1.1, there are four types of waste which are most amenable to source reduction. These are

- hard to treat,
- dispersible,
- hazardous or toxic, and
- high volume wastes.

These will be reviewed in a general way in this section. Wastes which occur universally in textile processing will be discussed in some detail here, but wastes which are specific to a particular process will be discussed as a review of that process in later sections.

Hard to treat textile wastes include primarily color, metals, phenols, toxic organic compounds and phosphates. The first two, color and metals, originate primarily from dyeing or printing operations, although metal sources are sometimes found in other processes. Phosphates are used primarily in preparation and dyeing. In addition to these three, other hard to treat wastes include non-biodegradable organic materials such as certain surfactants, solvents, etc. These can resist treatment, pass through standard activated sludge systems, and produce aquatic toxicity in effluent from treatment plants. Since the primary problem in that case is toxicity, these wastes will be reviewed under the hazardous and toxic category.

There are several ways to deal with hard to treat wastes from a source reduction point of view. These include

- chemical substitution, control and conservation,
- waste capture-reuse/recycle, and
- segregation.

Specific details of reduction of hard to treat wastes on a process-by-process basis will be given in the following sections.

The second type, highly dispersible wastes, can frequently be handled at the source. Textile examples of this type of waste are

- print paste, (especially from clean-up),
- lint,
- waste from coating operations (especially foam backcoatings),
- waste solvents from machine cleaning,
- still bottoms from solvent recovery, especially in dry cleaning operations, and
- batch dumps of unused finish mixes.

These materials can frequently be captured in the “dry” or concentrated form for disposal. In some cases, these materials may have salvage or recycle/reuse value, but even if not reused, disposal as well as collection and preparation for disposal is usually much easier if the material is captured when least diluted or contaminated. Sources of these wastes are universal in textile wet processing.

Pastes generally come from printing and can be either oil/water pastes or acrylic polymers. In either case, they tend to gel and form lumps in drains. Such wastes may be difficult to sample with automated equipment due to stoppage of sampler lines, pumps, and filters. Lint can originate from most textile operations, particularly preparation, dyeing, and washing operations. It is usually fairly easy to remove lint by primary control measures such as placing filters in the liquor circulation lines of dyeing machines and other equipment. These filters must be maintained and cleaned out on a regular basis in order to insure proper operation. The collected materials usually can be dried and then landfilled or incinerated.

Waste solvents originate from all types of machine cleaning and shop activities, as well as drum and print screen cleaning. A useful system for small parts cleaning consists of a bowl on top of a delivery tube above a reservoir as shown in Figure 1.4-1. When needed, solvent is pumped



up into the bowl where small parts to be cleaned are placed. A screen prevents the parts from falling into the tube and reservoir. After use, the solvent flows back down into the reservoir by gravity. This can also be used to wet rags with solvent for cleaning. In both cases, there is no need to dispose of leftover solvent which has been poured into a container. Contaminated solvent, whether from parts or machine cleaners or processing uses such as solvent scouring ranges or dry cleaning, can be recovered by distillation. Sludges, residues, and still bottoms not recovered should not be mixed with other wastes but disposed separately. In some cases (e.g. lanolin from wool dry cleaning), these may have commercial value.

It is only good economic sense to avoid dumping unused portions of chemical mixes. This happens in many types of continuous textile operations, such as slashing, preparation, continuous dyeing, printing, coating, and finishing. Source reduction techniques which apply include equipment modification, maintenance procedures, housekeeping, waste capture and, in all cases, segregation of these wastes from the general waste streams. Specific methods for the above example will be described in other sections of this handbook.

Hazardous or toxic wastes are generally a subgroup of hard to treat wastes. Their impact on the environment is great; therefore it is appropriate to discuss them as a separate class. For textiles, hazardous or toxic wastes include materials such as

- metals,
- chlorinated solvents,
- non-degradable surfactants, and
- other non-degradable or volatile organic materials.

These are often for non-process uses, such as machine cleaning. Appropriate reduction strategies, to be described later in this document, include conservation, substitution, process modification, and maintenance/housekeeping.

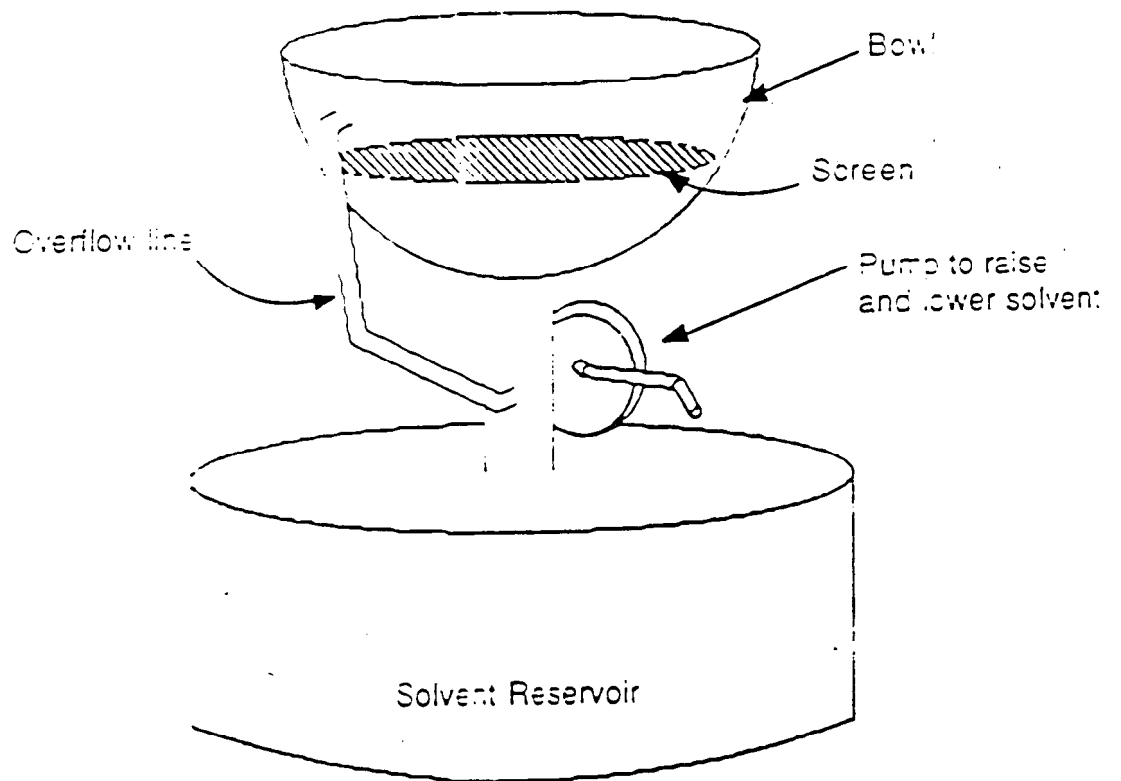
Large volume wastes are sometimes a problem in textiles, and the most common large volume wastes include

- hydraulic loading (high volume of wastewater),
- wash water from preparation and continuous dyeing,
- alkaline waste from preparation, and
- batch dye waste, especially containing large amounts of salt, acid or alkali.

These can sometimes be reduced by recycle as well as by process and equipment modifications. However, there are many cases where little or nothing can be done.

The reader may note that the above does not include some common waste “problems” such as BOD and COD. These, of course, are also subject to the same techniques of source reduction. However, from a waste treatment point of view, BOD *per se* does not represent a technical problem. Activated sludge systems easily handle BOD and, indeed, that is their design purpose. On the other hand, BOD may be an economic problem for textile wet processors who discharge their waste to a municipal system or POTW, due to treatment surcharges. Thus it may be desirable to reduce BOD (or COD), but care must be taken not to do so at the expense of increased aquatic toxicity, metal contamination, etc. However, the BOD “problem” is usually a political/economic issue, not a technical one. Some primary sources of BOD are

- wasted chemicals - batch dumps,
- starch size,
- knitting oils, and
- degradable surfactants.



## **I.5 Chemical Substitutions**

In many instances, several chemical alternatives exist for textile wet processing. Details of the particular process as well as cost factors dictate which is selected. Several such situations are reviewed in this following. Basic source reduction strategies are substitution, conservation, and process optimization,

### **1.5.1 Metals**

Metals are produced from several sources in textile processing, most usually from

- fiber,
- incoming water supply,
- pumps, pipes, valves, etc.,
- oxidizing and reducing agents, electrolyte, acid and alkali,
- dyes and pigments,
- certain finishes,
- herbicides and pesticides, and
- maintenance chemicals.

### **Textile Fibers**

Metals occur in natural fibers such as cotton by absorption from the environment during growth. Studies of raw cotton fiber have shown levels of metals of approximately 75 to 100 ppm. This means that a mill could expect this source to contribute up to 10 ppm total metal in the effluent. In addition, metal contamination from warp size, machinery, etc., can occur. Catalysts from polymerization and other sources can also contribute in the case of man made synthetic fibers.

### **Water Supply**

It is not at all unusual to find significant levels (>1 ppm) of copper, iron, and zinc in water supplies. Often copper is added to public water systems to prevent algae growth in tanks and ponds. Aluminum, in the form of alum, is also a commonly added material. These metals can also undergo ion exchange with plumbing (especially lead joints), valves, and pump parts to produce lead or other less electro-negative metals in the mill's effluent. Any attempt to reduce metal sources in a mill should include a study of the influent water. Such a study should be done each season, as the raw water quality generally will vary seasonally.

### **Oxidizing and Reducing Agents**

Traditionally, dichromate was used for oxidation of vat dyes until the 1960's. This, of course, contributed greatly to chromium content of effluent. This use has now been almost universally discontinued in favor of periodate or peroxide oxidizers. Another use of chrome oxidizing agents is in laboratory cleaning solutions. The strong oxidizing properties of this solution make it a valuable tool in the lab; however, there are significant problems associated with the use of this cleaning solution:

- Chromium is not readily rinsed from glassware and may be detrimental to microbiological work,
- Chromium is toxic in the aquatic environment,
- Chromium is highly toxic to bacteria present in sewage treatment facilities.

To avoid these problems, users can either:

1. Switch to non-dichromate solutions. These are readily available, very suitable, and produce non-toxic wastes when properly treated.
2. Not dispose of dichromate solutions in a sanitary sewer.

Certain other agents contain metals, notably zinc stabilized sulfoxylate reducing agents. These can be substituted with sodium hydrosulfite.

### **Metal - Containing Finishes**

There are also a few organo-metallic finishes such as water repellent, flame retardant, anti-fungal and anti-odor. These can contain antimony, tin and zinc. To reduce these metals at their source, care should be taken not to dump leftover mixes into the waste stream, but rather

- make up only the exact amount of finish needed,
- store and save all excess to be used on future runs,
- handle any dumping as a separate waste disposal procedure, and do not mix with routine wastes from processing.

### **D y e s**

Certain dyes contain copper or other metals as an integral part of the dye molecule. A review of dye structures in the Color Index indicates that most of these metal-containing dyes are either blue or green. There are many of these dyes, mostly in the 74000 series of chemical constitutions, which are phthalocyanine dyes and pigments. Examples are:

Vat Blue 29 .....	Cobalt
Pigment Blue 15 .....	Copper
Ingrain Blue 14 .....	Nickel
Ingrain Blue 5 .....	..Cobalt
Ingrain Blue 13 .....	Copper
Direct Blue 86 .....	Copper
Direct Blue 87 .....	Copper
Pigment Blue 17 .....	Copper, Barium
Acid Blue 249 .....	Copper
Ingrain Blue 1 .....	Copper
Pigment Blue 15 .....	Copper
Pigment Green 37 .....	Copper
Pigment Green 7 .....	Copper
Ingrain Green 3 .....	Copper
Solvent Blue 25 .....	Copper
Solvent Blue 24 .....	Copper
Solvent Blue 55 .....	Copper
Reactive Blue 7 .....	Copper

To reduce metals from this source, two things can be done. The first is to assure that these dyes are used only when absolutely necessary. In many cases other dyes can be substituted. Especially in the case of cellulose, metal-free vat dyes can be used for green

and blue shades in place of direct or fiber reactive dye types which contain metals. In addition, there is the option of replacing part of the required metal-containing dye with alternates which do not contain metals. Although this leaves some metal in the recipe, the amount is reduced.

The second step in reducing metals from this source is to insure the maximum exhaustion possible by allowing enough time, optimizing temperature, pH and salt concentration, fixative and other dyeing parameters.

### **Case History**

A survey of dyes, performed in the mid 1970s, showed that the primary source of copper in wet processing waste from a major North Carolina mill was from dyestuffs. A check of each of the dyestuff showed that approximately 95% of the copper in the effluent originated from 13 dyestuffs which were manufactured with high copper contents:

Name	Percentage Cu content
Belamine F Red 3BL	4.00
Belamine B Blue LT	3.68
Pyrazol F Violet MXD	3.00
Solantine Brown BRL	3.00
Atlantic Blue 8GLN-K	2.70
Atlantic Resinfast Blue 2R	2.50
Sirius Supra Turquoise LG	2.29
Superlitefast Blue 2GLL	1.00
Direct Navy OFS	0.70
Belamaine Red 3BL	4.00
Solophenyl Brown BRL	3.00
Fastolite Blue L	2.70
Atlantic Black NR	1.50

Each of these dyes contained copper as an integral part of the molecular structure of its chromophore; therefore, most of the metal would exhaust onto the fabric with the dye. However, direct dyes typically remain about 5% to 15% unexhausted in spent dye liquors. Thus some metal was discharged as waste. This particular mill did not use vat or fiber reactive classes for exhaust dyeing.

### **Other Sources**

Maintenance chemicals are an often overlooked source of toxic wastes. The typical textile mill usually has some sort of approval procedure and quality control for raw materials used in processing, but sometimes maintenance chemicals escape approval because they do not directly affect the mill's direct cost and quality control, and because they are purchased and used less frequently than process chemicals. Controlling and evaluating these materials should not be overlooked. Typical contents include metals, acids, methylene chloride, perchloroethylene, and other highly toxic materials.

Other types of nonprocess chemicals which have been known to contribute to metals (and toxicity) of wastewaters include biocides and herbicides. Biocides are frequently used in cooling towers and nonprocess water purification and processing. Biocides also

are used in certain applications, such as finishes for hosiery, tents, awnings and tarpaulins. Herbicides are used to control grass, weeds and other vegetation near bulk storage tanks, such as areas within a spill control berm, especially around tanks of flammable materials such as natural gas, LP gas, fuel oil, and varsol.

One final source is photographic processing. Occasionally, mills have photo processing equipment in house either for print screen making or other operations. In view of the high value of silver, this metal can be recovered from photo processing waste for both a source reduction and economic gain.

### **1.5.2 Phosphates**

Phosphates are used in several areas of textile wet processing, including

- buffers,
- builders for scouring,
- water conditioners,
- surfactants, and
- flame retardant finishes.

In many cases, substitutions can be made as shown in Table 1.5.2-1. These are much more economical generally than phosphate removal by treatment.

Table 1.5.2-1  
**Phosphate Substitutions**

<b><u>Source</u></b>	<b><u>Use</u></b>	<b><u>Substitute</u></b>
MSP	Acid salt, pH adjustment	Acetic acid
TSPP	Alkali, water conditioner	Soda ash
Phosphoric acid	Strong acid, pH control	Hydrochloric Acid
TSP	Alkali, builder for detergents	Caustic or soda ash
Hexaphos Calgon	Water conditioner	EDTA Silicate
Phosphate Esters	Surfactants, scouring	Ethoxylates or quaternary amines
Phosphates Phosphonamides	Flame retardants	Varies

In almost every case, there are alternatives to the use of phosphates. The exception to this is flame retardants. In the case of flame retardant finishes, substitution is not generally possible. However, batch dumps from flame retardant finishing can be controlled by the methods already discussed in Section 1.4.

### **1.5.3 Surfactants**

Another group of materials which frequently contribute to aquatic toxicity problems in textile wastewater includes surfactants, detergents, emulsifiers, and dispersants. These are widely used in preparation, dyeing and finishing. They can also originate from the fabric yarn or fiber itself, which usually has contaminants and processing assistants from previous processes such as

- spin finishes (synthetic fiber),
- natural oils and waxes (natural fiber),
- winding emulsions,
- coning oils,
- yarn finishes,
- knitting oils,
- warp size, and
- miscellaneous lubricants.

Surfactants are blended into nearly every chemical specialty to improve solubility/dispersability, to suspend water insoluble materials in processing and baths, and to improve product compatibility with other processing assistants. In addition to these sources, surfactants are used widely in textile processing to insure even, thorough and rapid wetting and penetration of processing solutions into textile substrates. The action of surfactants is to lower inter-facial tension of water and other materials at phase boundaries. Unfortunately, this same feature causes surfactants to be toxic to aquatic life. Therefore, in order to reduce the aquatic toxicity of textile wastes, the surfactants must be either eliminated or degraded via biological wastewater treatment systems. Surfactants vary widely in their characteristics with respect to biodegradation, therefore changing the surfactant in a textile process can have a great effect on the treatability of the textile waste as well as the toxicity of the treated waste. Many studies have been done to evaluate treatability and toxicity of surfactants.

Some of the more important surfactant types are listed below.

#### **Nonionic Surfactants**

Nonylphenol ethoxylate (AP) - emulsifier, wetter, scouring, low cost

Diethanol cocoamide (DEC) - scouring, dyeing assistant, lubricant, wool filling, softener

Linear alcohol ethoxylate (LAE) - uses similar to AP

#### **Anoionic Surfactants**

Dodecyl benzene sulfonic acid (DDBSA) - wetting, scouring, foaming, retarder

Sodium lauryl sulfate (SLS) - scouring, afterwash

Sulfated ethoxylated alcohol (SEA) - foaming, scouring

Naphthalene sulfonic acid (NSA) - dispersant for disperse dyes

### Cationic Surfactants

Tallow amine ethoxylate (TAE) - dyeing assistant, antistatic, decoupler, leveling agent

Alkyl dimethyl benzyl ammonium chloride (ADBAC) - antistat

The aquatic toxicities and ease of biodegradation of these substances vary greatly due to factors which are not completely understood. However, these materials accumulate within aquatic organisms and at surfaces such as the gills of fish, and interfere with the function of these aquatic life sustaining organs.. One important factor in a surfactant's toxicity is the HLB (hydrophilic/lipophilic balance) of the surfactant.

Relative toxicities of many surfactants as determined by Burlington Research Corporation in untreated solutions are shown below.

<u>Surfactant</u>	<u>Acute 48 hours static LC50 for Daphnia pulex</u>
AP	13 ppm
DEC	2 ppm
LAE	5 ppm
DDBSA	20 ppm
SLS	28 ppm
SEA	20 ppm
NSA	data not available
TAE (15 mol E-0)	4 ppm
TAE (150 mol E-0)	66 ppm
ADBAC	<1 ppm

This shows that there is considerable variance in toxicity even between similar types of surfactants. A general trend, however, seems to be that (other factors being equal) surfactants with higher HLB (i.e. those which contain more hydrophilic groups) have lower toxicity. This toxicity data should be kept in mind when selecting surfactants for use or when considering substitutions.

Aside from the toxicity of these surfactant materials, one must also consider their degradability or treatability. A surfactant of moderate or low toxicity which will not degrade (therefore passing through a treatment system) will produce more toxic waste than one of higher toxicity which is degraded fully during treatment. Generally, the rule of thumb for degradability is that the more linear the molecule, the greater its degradability, Branched hydrophobes have less degradability than linear, and aromatic materials are least degradable. For example, AP (aromatic type) was degraded about 25% while under similar conditions, LAE (linear type) was degraded 100%. Although LAE had a higher toxicity (LC50 = 2 ppm), compared to AP (LC50=13 ppm), prior to treatment, treated effluents show substantial toxicity for AP but no toxicity for LAE. Of course, the LAE will have higher BOD than AP, due to its degradability. Also, LAE shows no less degradability at low temperatures, where as AP is much less degradable at lower treatment temperatures.

Thus one strategy for reduction of toxicity of wastewater is to substitute LAE for ethoxylated octyl or nonyl pnenol (AP) wherever possible. Unfortunately, the opposite substitution frequently occurs when a mill is required by a POTW to meet a low BOD limit. The tendency is to seek out products with lower BOD. These frequently are the less



degradable types which tend to pass through a treatment system to create aquatic toxicity problems. So, in the case of chemical substitutions of this type, the situation is not always clear, and can be complicated by several problems.

- Lack of BOD, aquatic toxicity, and other data from suppliers
- Difficulties in correlating data on pure products to the effects in spent dye liquors and other waste streams
- Difficulties in evaluating trade-off effects such as BOD vs toxicity
- Proprietary nature of chemical specialties
- Most specialties are mixtures

One way to evaluate the potential for oxygen demand/toxicity problems for a product or waste stream is to take into account both the COD and BOD of the material. These quantities are related in such a way that COD:BOD ratio is typically 2.5:1 to 5:1 for textile waste streams. Any waste stream that has a very high (above 5:1) COD:BOD ratio indicates poor biodegradability of material. In many cases, BOD alone is not an adequate indicator of biodegradability.

### **Case History**

The City of Mount Airy in Surry County, NC operates a trickling filter POTW for its population of 7600 people as well as 14 textile industries. The effluent from this system was identified as being high in aquatic toxicity, containing potentially toxic levels of copper, zinc, and surfactants - especially alkyl phenol ethoxylates (AP's). The City of Mount Airy requested each textile industry to review its use of the offensive materials, and to substitute, eliminate, or optimize/reduce chemical use in each case. Within 60 days, the toxicity of waste from the treatment system decreased substantially. This was attributed primarily to substitution of LAB for AP.

Prior to the industrial source reduction efforts, toxicity (48 hours LC50 static daphnid bioassay) was 51%. Afterwards, this was reduced to a level of >90% and regularly passed NCDEM Ceriodaphnia pass/fail mini-chronic bioassay.

#### **1.5.4 Solvents**

Organic solvents are used in textile wet processing, either as emulsions in water or in their natural form (non-aqueous). Most frequently, solvents used to process the textile substrates are emulsified. Non-aqueous solvent processing attracted considerable interest during the 1960's and 1970's, but never attained much commercial success, except for dry cleaning operations. Typical solvent emulsions include scouring agents and dye carriers for synthetic fibers, especially polyester. These materials typically exhaust into the fiber and later are evolved from driers as airborne volatile organic compounds (VOC's). Examples of such materials include

- methyl naphthalene
- trichlorobenzene
- chlorotoluene
- ortho dichlorobenzene
- perchloroethylene
- methyl ester of cresotinic acid
- butyl benzoate
- biphenyl

These can become part of the wastewater stream through spills, leaks, clean up (drums, tanks), batch chemical dumps and poor housekeeping. For scouring, the more objectionable chlorinated materials can be replaced with non-chlorinated materials (such as xylene for chlorotoluene).

Solvents in non-aqueous applications are frequently used for machine cleaners, parts degreasers, and laboratory use, such as extraction procedures. Reduction of wasted solvents such as machine cleaners and degreasers can be effected by using a device described in Section I.4 (see Figure 1.4-1), or by using substitutions.

Laboratory or machine cleaning solvents should never be disposed of in a sanitary sewer. Instead, solvent recovery bottles should be available for later pickup and proper disposal. It usually is a cost advantage to keep different types of solvents separate, since disposal methods vary. Separate waste containers should be available for

- chlorinated solvents,
- non-chlorinated solvents, and
- water-free oils.

Also, the use of chlorinated solvents in the laboratory should be minimized, particularly by substituting Freon®, xylene, or toluene for chlorinated solvents (such as methylene chloride, perchloroethylene, or chloroform) or substitution of less toxic or hazardous solvents (such as toluene for benzene).

## **I.6 Process Modifications and Alternatives**

Often it is possible to change a textile production process in such a way that waste is greatly reduced or eliminated. This change is usually very site-specific, and depends on which products are being produced, the quality required, and waste reduction goals. Such changes also often result in an economic gain for the processor. Several broadly applicable techniques will be reviewed in this section. These include:

- water conservation,
- dyebath reuse,
- pad/batch dyeing,
- foam processing,
- heat/energy recovery,
- size recovery, and
- caustic recovery.

### **1.6.1 Water Conservation**

One technique which can usually render both cost savings and waste management through source reduction for textile mills is the practice of water conservation. It is not unusual to find situations where 10% to 30% reduction in water can be realized.

Commonly observed sources of water waste are:

- hoses left running,
- broken or missing valves,
- excessive water use in washing operations,
- cooling water left running when machinery is shut down, and
- defective toilets, water coolers, etc.

Several methods have been used to recover an&or segregate wastewater streams. Once-through noncontact cooling water can be reused by sending it back to a clear well or influent water line to the mill. This can result in significant water savings.

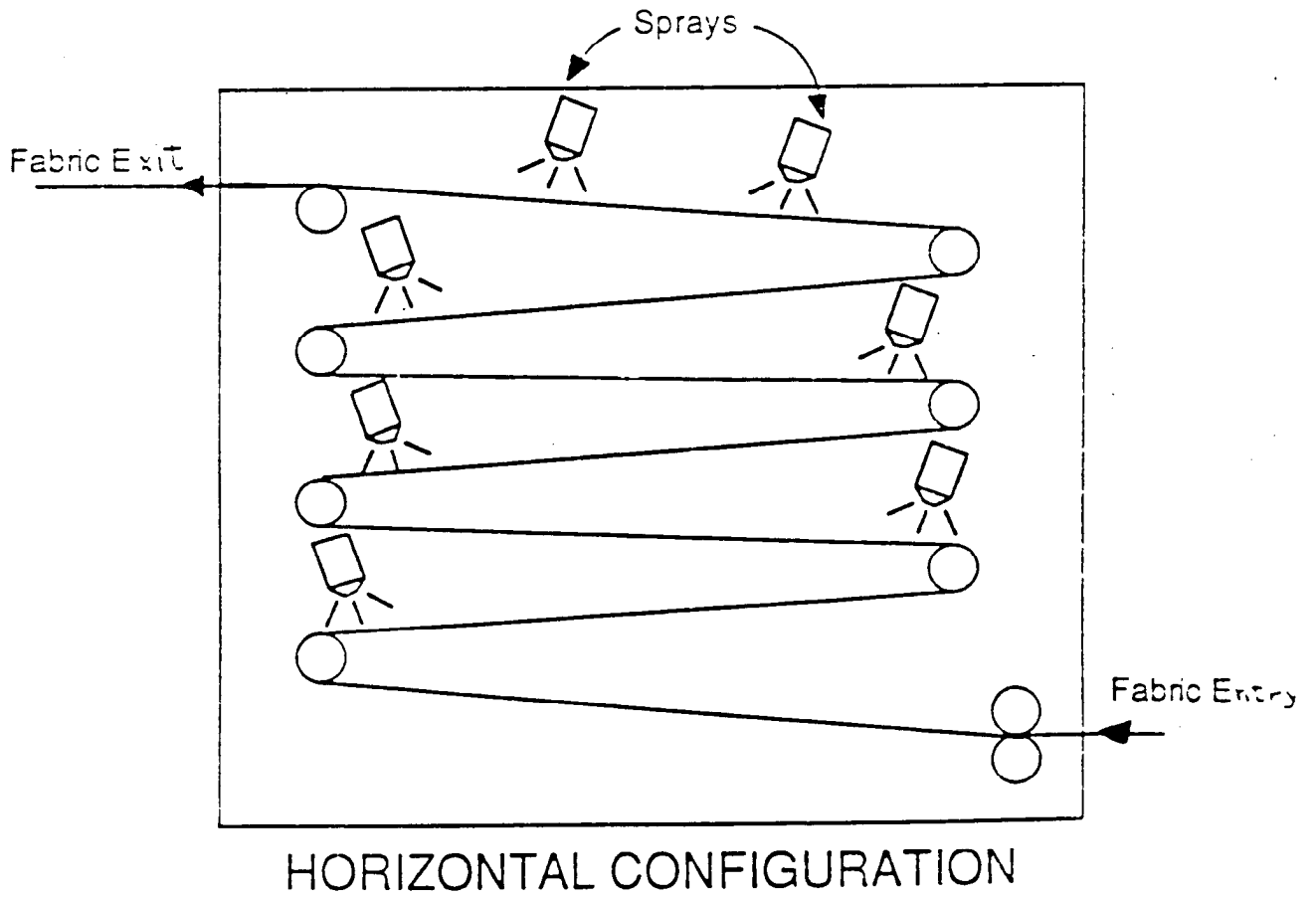
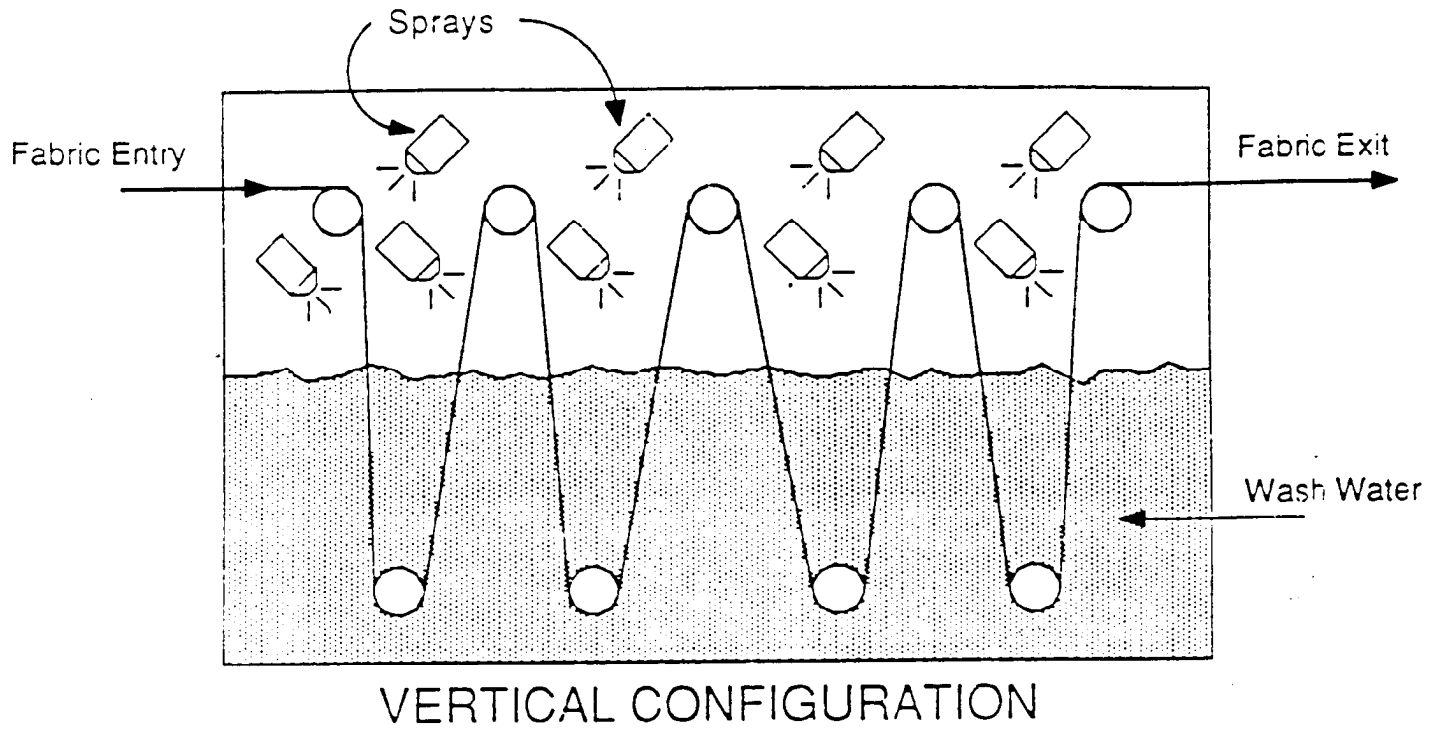
Waste streams from roof drains and parking lot drains, from cooling water sources, from process wastewater, and from domestic waste can sometimes be segregated, treated, and discharged separately and more economically to a mill's advantage. This results in less hydraulic loading of contaminated water going to the treatment system. Details are usually site-specific.

Most wastewater from textile wet processing comes from washing operations, primarily in preparation or dyeing. Since preparation processes are typically continuous, well-known techniques such as counter current washing can be used to great advantage for water conservation in washing processes.

### **Counter Current Washing**

The principle of counter current washing is simple, and it is usually not expensive or difficult to implement. Basically, the least contaminated water from the final wash is reused for the next-to-last wash and so on until the water reaches the first wash stage. Then it is discharged. This is a useful technique for washing after such processes as continuous dyeing, desizing, scouring, or bleaching. An important variant in this idea is the "horizontal" or "inclined" washer concept. This arrangement is shown in Figure 1.6.1-1. These machines made quite an entrance several years ago when they were first introduced. The efficiency of a horizontal or inclined washer is much higher due to the inherent countercurrent nature of the water flow within the machine. The operation in terms of the theory of washing is excellent and very efficient. However, some of these machines have lost their wide acceptance and a few manufacturers of washers have

Figure I.6.1-1



gone back to the vertical configuration. The reason for this apparent inconsistency is that although the performance of these washers, in theory, is excellent, the mechanical construction has to be much better on a horizontal or inclined washer than on a vertical one. Sloppy roll settings, undersized rolls, out of line, uneven, bent, bowed, biased, bearing play, or other misalignments within the machine are not so critical in a vertical washer. However, in a horizontal or inclined washer, the alignment of all parts of the washer must be almost perfect, or else the weight of water pressing down on the fabric can cause it to sag, balloon, or stretch. Thus the horizontal or inclined type washer can get a bad name primarily because of mechanical problems in the design and construction. Some companies realized the additional mechanical requirements that would be required from this type of machine, and produced a very rugged and very precise machine. Thus, if properly constructed, horizontal or inclined washers can produce a high quality fabric without mechanical problems and give much better washing efficiency with reduced water use.

### Water Consumption of Batch Dyeing Machines

Different types of dyeing machinery use different amounts of water. There are many “low liquor ratio” dyeing machines which are purported to save water. The liquor ratio is the ratio of amount of water (in pounds) in the exhaust dyebath to amount of fabric (in pounds). This differs greatly between machine types. However, most water in dyeing operations is used for washing, and not in the dyebath itself. Thus it is not necessarily true that a dyeing machine with 10:1 liquor ratio will use half as much as a dye machine with 20:1 liquor ratio. Table I.6.1-1 shows typical values for liquor ratios and water consumption for various types of dyeing machinery.

Table I.6.1-1

Dyeing machine	H <sub>2</sub> O consumption [20] gal/#	Typical liquor ratio liquor/goods at time of dye application
Continuous	20	1:1
Beck	23	17:1
Jet	24	12:1
Jig	12	5:1
Beam	20	10:1
Package	22	10:1
Paddle	35	40:1
Stock	23	12:1
Skein	30	17:1

In general, the heating of dyebaths constitutes the major portion of the energy consumed in dyeing; therefore, low liquor ratio dyeing equipment represents major energy savings as well as reduction in steam use and the resulting air pollution from boilers. But the washing efficiency of many types of low liquor ratio dyeing machines, such as jigs, is

poor. Washing efficiency depends on mechanical factors, such as bath and fabric turnover rate or “contacts”, liquor ratio, turbulence and other mechanical considerations and physical flow characteristics. Thus, low liquor ratio and reduced total water use do not always correlate as closely as one might expect.

### **Wastewater Recycle in Preparation**

Preparation processes, especially desizing and scouring, can be done on many types of equipment, both continuous and batch. These are usually the largest water consumers in a mill. The continuous processes have great potential for wastewater recycle/reuse since the waste stream is continuous, fairly constant in characteristics, and usually easy to segregate from other waste streams.

Examples of waste stream reuse in a typical bleach unit processing polyester/cotton and 100% cotton fabrics would include

1. Recycle J - box or kier drain wastes to saturator,
2. Countercurrent washing,
3. Recycle wastewater from continuous scour operation for batch scouring.

Of course, preparation chemicals (including especially optical brighteners and tints) must be selected in such a way that reuse does not create quality problems such as spotting.

The situation with batch scouring and bleaching does not allow, in general, for recycle/recovery of waste streams because:

- The streams occur intermittently.
- The streams generally dump into pits and are not easily segregated.
- The liquor ratios are much higher (typically 10:1 to 20:1) in batch preparation; therefore, the wastes are more dilute.
- Preparation steps are frequently combined.

### **1.6.2 Dyebath**

The idea of dyebath renovation and reuse began attracting attention around the middle 1970s when energy costs became a critical factor in overall manufacturing costs. Dyebath renovation and reuse has been shown to be a feasible method of cost reduction, energy savings, and waste source reduction in some textile wet processing applications. Laboratory studies, pilot plant work, and full scale commercial use have been documented. This section summarizes these documented studies and presents typical examples of comparative procedures; however, this technique has not really caught on in commercial production.

As early as 1964, it was estimated that about 10% to 16% of textile wet processing wastewaters were reclaimed or recycled. Modern water and energy conservation practices, including strategies such as dyebath reuse, make it possible for wet processors to increase this figure dramatically, with corresponding cost savings and waste reduction.

Dyebath reuse is an attractive alternative to pretreatment systems for dyehouses that discharge to POTWs. In many cases, dyehouses operating in cities do not have enough space to construct large pretreatment systems. Dyebath reuse, which has been shown to reduce flow, BOD, and COD loadings up to 33%, requires a smaller investment in equipment than pretreatment systems. Also, the dyebath reuse concept has a return on investment in the form of dye, chemical, and energy savings which pretreatment does not.

Savings, as well as installation costs and operating expenses, are site-specific. Based on case histories available to date, the data in Table 1.6.2-1 generally summarizes the magnitude of these factors. The payback period is generally 13 to 20 months.

Table 1.6.2-1

Typical Cost and Savings Figures for Dyebath Reuse per Dye Machine

---

Lab and support equipment (one set required)	\$9,000
Machine modifications, tanks, pumps, pipes	\$15,000 to 25,000
Annual operating costs	\$1,000 to 2,000
Annual savings (total)	\$21,000
Dyes and chemicals	\$15,000
Water	\$750
Sewer	\$750
Energy	\$4,500

---

Dyebath reuse consists of 4 steps:

1 . Store the spent dyebath in a tank or move to a second identical dyeing machine. One interesting application of dyebath reuse involves moving the dyebath back and forth between two or more machines. For example, package dyeing machine (A) can be preparing yarn while a second identical machine (B) is in dye. When B completes its dye cycle, the bath is pumped to A for renovation and dyeing. In the meantime, the yarn in B is afterscourd, unloaded, and a new batch is loaded and prescourd. By that time, A has finished dyeing, and the bath goes back to B for another reuse cycle, etc.

2. Analyze or estimate the dye and chemical content of spent dye liquor spectrophotometer and/or guidelines based on specific production experience. Equipment for this is commonly available at a cost of under \$10,000. Unexhausted dyestuff is measured by solution coloristic measurements, sometimes using extraction techniques if the bath is turbid.

Chemical losses are determined by specific production experience based on exhaust, volatilization, and dye liquor carry-off with the dyed substrate (usually about 10 to 15%). Chemical losses may be estimated or determined analytically if appropriate equipment is available. Usually the quantities are not as critical as the dye, and an estimate is sufficient.

The procedure for extracting dye from the dyebath is as follows:

- Add 20 ml (25 grams) of salt, 25 ml of exhausted dyebath, and 25 ml of a solvent such as 1-octanol or toluene in succession into a clean separatory funnel.

- Place stopper in funnel and shake vigorously for 30 seconds. Allow contents to separate for 30 seconds. Shake vigorously again for 30 seconds. (This mixing action results in extraction of dyes from the dyebath water into the solvent.)
- Place funnel on ring stand and allow for distinct separation of salt (bottom layer), water (middle layer), and solvent with dyes (top layer). Solvent layer may appear cloudy due to water in the solvent.
- Remove stopper. Open the stopcock and allow the salt and water layers to drain out to sink. Close stopcock.
- Place two cotton balls in clean, dry syringe. Drain solvent layer from funnel into syringe.
- Allow solvent to pass through cotton balls in syringe to absorb any remaining water, and collect sample in a clean, dry sample cell as it leaves the syringe.

3. Add make-up amounts of dyes and chemicals to renovate the spent bath. Also add water to make up the volume that is carried off by the dyed substrate.

4. Reuse the bath for another dyeing. Because the used dyebath will usually be hot (over 140<sup>0</sup>F), it must be cooled down to an appropriate temperature for starting the next dyeing. Considerable time and energy are saved by starting the next dyeing at the highest possible temperature consistent with desired quality factors. This is one of the main advantages of dyebath reuse. The ultimate “life” of a dyebath varies according to the quality required, contaminant buildup, and other factors.

### **Dye Classes and Potential for Bath Reuse**

There are many different classes of textile dyes, and each class applies to specific fiber types and requires different exhaustion procedures, specialty chemicals, pH, equipment, etc. Because of these differences, the savings that can be expected vary. Also, results may vary with respect to the fastness, shade reproducibility, and other factors.

Batch dye systems have been reported to be adaptable to dyebath reuse as shown in

T a b l e 1 . 6 . 2 - 2 .



Table 1.6.2-2

Systems for Dyebath Reuse

Produce	Fiber	Dye class(es)	Machine
Knit fabric	Polyester	Disperse	Jet
	Cotton	Reactive or direct	Beck
	Poly/cotton	Disperse/reactive or direct	Beck
Yarn package	Polyester	Disperse	Package
	Poly/cotton	Disperse/reactive or direct	Package
Socks	Nylon/spandex	Acid	Paddle
Pantyhose	Nylon/spandex	Disperse/acid	Beck
Carpet	Nylon	Disperse/acid	Beck
	Polyester	Disperse	Beck
Woven fabric	Aramid	Basic	Jet
Skein	Acrylic	Basic	Skein

No case history has been published for direct dyes on cellulose; however, this could also be done and would result in chemical savings of salt, leveler/retardant, dye, surfactant, lubricant, and defoamer. Dyebath reuse would likely be limited by contaminant buildup of two types:

1. Fabric impurities not removed during preparation.
2. Emulsifier systems wetters and dispersants from dye, retarder, etc. These should be of fairly minor importance, and dye reuse should be possible for 15 or more cycles.

A laboratory study of reuse of disperse dyes on 100% polyester spun yam (package dye) showed that nine reuse cycles could be expected, with savings of about 80% on water and chemicals, and about 40% on energy.

**Limitations of Dyebath Reuse**

To gain the maximum benefit from dyebath reuse, users must keep certain considerations in mind. The easiest systems to manage for dyebath reuse are dye classes that undergo minimum changes during the dyeing processes. These are:

1. acid dyes for nylon and wool,
2. basic dyes for acrylic and certain copolymers,
3. direct dyes for cotton, and
4. disperse dyes for synthetic polymers.

A higher degree of difficulty can be expected from other classes (vat, sulfur, fiber reactive). The easiest situation to manage is the reuse of a dyebath to repeat the same shade with the same dyes and equipment on the same fiber. It is also possible to reuse a dyebath to produce a darker or lighter shade with the same dyestuff selection on the same fiber. More difficult

situations would involve addition of new colorants to renovate a dyebath. This would lead to potential problems with shade matching and metamerism.

The number of reuse cycles for a dyebath is limited by buildup of impurities. These impurities can come from several sources. One source is fabric impurities from incomplete preparation, which include natural impurities in cotton and wool, knitting oils, winding waxes and emulsions, fiber finishes, size materials and the like. Impurities can also accumulate from dye diluents, salt buildup from addition of acids and bases for pH control, steam contaminants for direct steam heated baths, and emulsifier systems from exhausted chemical specialties. Many impurities are surfactants, and these can cause stripping and/or retarding of dye exhaust if allowed to buildup excessively. Other problems such as spotting and excessive foaming can occur if too many reuse cycles are attempted. The usual range of reuse cycles is 5 to 25, and each process and/or shade must be optimized by actual production experience.

Specialty dye assistants and other materials which are essential to a dyeing process may be lost by several mechanisms. These include losses due to vaporization from open dyeing machines, exhaust 'onto the fabric, chemical reaction, and drag-out by the substrate. These losses may vary from 10% upward and may vary between components of a blended chemical specialty. To insure best results, dyeing assistants must be carefully screened for reuse performance.

One major reason for using batch (exhaust) dyeing is the ability to produce small lots, short runs, and fast turnaround times. Because dyebath reuse requires special scheduling considerations, it may somewhat limit the flexibility of batch dyeing operations.

In summary, batch dyebath reuse may not be for every situation; however, the economic savings are large, if properly applied, and the waste reduction is substantial when this technique can be used.

### **Case History #1**

Perhaps the most extensive and best documented study on dyebath reuse was carpet dyeing done by Bigelow in the summer of 1983. In this work, carpets were dyed with conventional (Procedure 1.6.2-A) and with dyebath reuse (Procedure 1.6.2-B). Results of quality, savings, and waste reduction were carefully documented in detail. Some of the more interesting data relating to waste reduction show that BOD and COD were reduced by over 30% and phosphorous, phenolics, and total dissolved solids were reduced by 50% and 80% (see Table 1.6.2-3).

Dyeing in Bigelow production runs were done on two different shades and styles of carpet. A pair of conventional atmospheric becks were used, and dyebath was pumped back and forth between them. Over twenty reuse cycles occurred. Savings were estimated to be over \$60,000 per year per pair of becks.

Procedure I.6.2-A

Conventional Carpet Dye Procedure

---

1. With beck drain closed, load carpet into beck using spray to assist in moving carpet over reel.
2. Fill beck with cold water.
3. Add auxiliary chemicals to the beck; continue mixing for five minutes after all chemicals have been added.
4. Measure pH and adjust if necessary.
5. Add dyes and mix for 10 minutes.
6. Raise dyebath temperature to 180°F at 3°F per minute.
7. Dye at 180°F for 30 minutes.
8. Patch and, if necessary to obtain acceptable dyeing, perform add(s). (After each add, dyeing is performed for 15 additional minutes.)
9. Add cold water with beck drain open to cool to 150°F or lower. Shut off water and drain beck.
10. Close drain and fill beck, cold water to rinse, cool, and float carpet.
11. Drain and flush beck to prepare it for next dyeing.

### Procedure I.6.2-B

#### Modified Procedure for Carpet with Dyebath Reuse

---

1. With beck drain open, load two rolls of carpet onto beck using spray rinse (tint added to greige carpet is removed from carpet yarns during spray rinse; for reconstituted dyeings, the drain is left open to prevent tint buildup in recycled dyebaths).
2. Close drain. Arrange and connect dyebath transfer equipment into appropriate orientation. Set flowmeter totalizer to zero: Pump dyebath to new beck from beck used for previous dyeing.
3. Add auxiliary chemicals to beck; continue mixing for five minutes after all chemicals have been used.
4. Measure pH and adjust if necessary.
5. Add dyes and mix for ten minutes.
6. Raise dyebath temperature to 180°F at 3°F per minute.
7. Dye at 180°F for 30 minutes.
8. Sample and, if necessary to obtain acceptable dyeing, perform add(s). (After each add, run 15 additional minutes.)
9. Add cold water with beck drain closed and cool to approximately 140°F. (Some exhausted dyebath will be lost through overflow ports.) Collect dyebath sample for absorbance measurement. Pump to new beck (Step 2 of subsequent dyeing cycle). Perform solvent extraction of dyebath sample, perform absorbance measurements and calculate amounts of dyes and auxiliary chemicals required for next dyeing. Drain.
10. Close drain and fill beck, cold water to rinse, cool, and float carpet.
11. Unload carpet. Drain and flush beck to prepare for next dyeing.

---

**Table 1.6.2-3**

Pollution Reduction Results  
Dyebath Reuse for Carpet

---

Pollutant	Conventional	Pollutant loading Carpet style I Dyebath reuse	Reduction
BOD (g/kg)	23	15	35%
COD (g/kg)	56	3	30%
TSS (g/kg)	0.53	0.26	51%
TDS (g/kg)	31	14	55%
Phenolics (mg/kg)	1.5	0.8	47%
Total-P (g/kg)	2.8	1.0	64%

---

### **Case History #2**

Adams-Millis Company had practical dyebath reuse in plants at High Point and Franklinton, NC. In both cases, nylon pantyhose were dyed in rotary paddle machines with disperse dyes. The results were so good that 95% of the rotary drum machines at the Franklinton plant are reportedly run dyebath reuse systems.

The idea of reuse was also used in these operations in another way. The final softener bath was reused as a prescour for the next batch to remove oils, fiber finish, etc., before dyeing. Cost savings were estimated at 2c/lb of goods produced. Conventional and reuse procedures are shown (Procedures 1.6.2-C, D and E).

### **Case History #3**

Evans & Black Carpets instituted dyebath reuse at its Dalton, GA, plant for the disperse dyeing of nylon carpets. The result was a projected savings of \$115,000 annually to the mill using eleven becks. At this time, 45% of the plant's production is reportedly dyed with reused baths. It was confirmed in this production situation that buildup of surfactants during the repeated reuse cycles causes slight decreases in the disperse dye exhaust. In general, this can be compensated by increasing the dye concentrations slightly as reuse cycles increase.

### **Case History #4**

Basic dyes are normally exhausted from acidic baths for acrylic and certain other copolymer materials. One case history relating to dyeing basic dyes on Nomex in jet dyeing machines is available.

Procedure I.6.2-C

Disperse/Nylon

Conventional Adams-Millis Procedure for Dyeing Pantyhose

---

Step

1. Fill with cold water.
2. Add auxiliary chemicals, run 3 minutes.
3. Raise temperature as rapidly as possible to 160°F.
4. Add disperse dyes, start basket turning.
5. Run machine 2 minutes.
6. Load goods evenly while turning machine downward into bath.
7. Run 45 minutes at 160°F.
8. Sample; make add if necessary.
9. Dump the bath.
10. Refill with cold water.
11. Inject steam rapidly to reach 110°F.
12. Add finish chemical and run 10 minutes at 110°F.
13. Dump the bath.
14. Unload the goods.

Approximate running time (zero adds) = 1 hour 40 minutes (100 minutes)

---

Procedure I.6.2-D

Disperse/Nylon

Reuse Procedure with Prescour for B-cycle and 17-cycle Sequences

---

Step

1. Load goods evenly in machine full of softener water from previous cycle.
2. Run for 5 minutes.
3. Drop prescour bath to drain.
4. Unload wet hose from machine.
5. Drop dyebath into machine (130-140 gallons).
6. Add water until 160 gallons reach on sight glass.
7. Raise temperature as rapidly as possible to 160°F with rotation.
8. Add auxiliary chemicals.
9. Add dispersed dyes.
10. Run 2 minutes.
11. Reload goods evenly while turning downward.
12. Run 45 minutes.
13. Sample; make add if necessary.
14. Sample dyebath for analysis.
15. Pump dyebath to holding tank and drain residual water in machine.
16. Add 160 gallons water (fill to 200 gallons on sight glass).
17. Raise to 110<sup>0</sup>F.
18. Add finish chemical.
19. Run 10 minutes.
20. Unload goods.
21. Return to step 1.



Procedure I.6.2-E

Disperse/Nylon

Reuse Procedure without Prescour for 14-cycle Sequence

---

Step

1. Drop dyebath into machine (130-140 gallons).
  2. Drain side pipe.
  3. Add make-up water to 190 gallons on sight glass.
  4. Add steam to 160°F.
  5. Add auxiliary chemicals.
  6. Add disperse dyes (plus 3 gallons water).
  7. Load goods (dry).
  8. Run 45 minutes at 160°F.
  9. Sample; make add if necessary.
  10. Sample dyebath for analysis.
  11. Pump dyebath to holding tank.
  12. Add 160 gallons of fresh water (to 200 gallons on sight glass).
  13. Raise to 110°F.
  14. Add finish chemical (plus 3 gallons water).
  15. Run 10 minutes.
  16. Drain softener bath.
  17. Unload goods.
  18. Return to Step 1.
-

In these evaluation trials, dyebaths were reused up to 15 times successfully. Capital expenses to install the equipment necessary to accomplish dyebath reuse were determined to be about \$15,000. Savings were estimated to be \$120 to \$140 per dye cycle (500-700 lbs) for a cost reduction of 17¢ to 28¢ per pound. The annual savings to the mill was estimated at \$100,000.

In this data, like the Adams-Millis study, there was uneven depletion of various components of dye carrier during the dye process. This required a reconstitution of 65% for dye carrier compared to 10% for other chemicals.

### **Case History #5**

Acid dyeing of nylon carpet using reconstituted dyebaths was done on atmospheric becks. Dyebath reuse was limited to 10 cycles due to buildup of salt. This reuse led to an annual savings estimated at \$31,300 compared to a total cost of \$15,000 for installation of necessary equipment.

#### **1.6.3 Pad/Batch Dyeing**

The pad batch (cold) method of dyeing cellulose is hardly a new concept. It has been quite successful in a wide variety of applications. Benefits include essentially eliminating the need for salt or chemical specialties from the dyebath, with associated cost savings and waste reduction. In many ways, it is one of the most reliable and easiest-to-control methods available today for certain applications. Strangely enough, however, it has not caught on in this country to the extent that it is used in other parts of the world.

To quickly summarize the pad batch method, prepared fabric is impregnated with liquor containing premixed fiber reactive dyestuff and alkali; excess liquid is squeezed out on the mangle; the fabric is batched onto rolls or in boxes, and covered with plastic film to prevent absorption of CO<sub>2</sub> from air or evaporation of water, then stored for two to twelve hours. The goods can be washed off in any of several conventional ways, depending on equipment available in the mill.

The method is interesting because it offers several significant advantages, primarily in its waste reduction, simplicity, and speed. Production of between 75 and 150 yards a minute, depending on the construction and weight of the goods involved, is commonly reported. In fact, this kind of speed can make the limiting factor the wash-off facilities, which may not be able to keep up.

Another factor that has generated enthusiasm for pad batch is its flexibility, compared to a continuous range. Either wovens or knits can be done, and in many constructions. Frequent changes of shade are no problem because reactives remain water soluble, making cleanup easy. This fits many situations well, especially when versatility is required.

Production case histories have shown that pad batch dyeing for cotton, rayon and blends conserves energy, water, dyes and chemicals, labor and floor space. Salt consumption is reduced from about 100% on weight of goods to zero. Water consumption for pad batch dyeing with beam wash-off is typically under two gallons per pound of dyed fabric, compared to typically 20 or more gallons on atmospheric becks for the same fiber reactive dyed shades. Energy consumption is similarly reduced from about 9000 BTU's per pound of dyed fabric for becks to under 2000 BTU's per pound for pad batch with beam washing. Chemical use, including alkali as well as specialty chemicals with associated BOD and COD loadings for waste streams, can be reduced up to 80% compared to atmospheric becks. Labor costs are also reduced. For example, two workers per shift can dye 200,000 pounds of fabric per five-day week.

In general, the quality of pad batch dyeings is equal to or better than other dyeing systems. Specific cost information is shown in Table 1.6.3-1, -2 and -3. These were prepared and originally published by Cotton Incorporated. Pad batch dyeings require highly reactive "cold dyeing" fiber reactive colors. Examples of brand names of such colors are:

Atlafix CX	(Atlantic)
Cibacron F	(Ciba Geigy)
Drimarine K	(Sandoz)
Intracron C	(C & K)
Levafix E (A)	(Mobay)
Procion MX	(ICI)
Remazol	(Hoechst)
Sumafix	(Wright)

Equipment for pad bath dyeing consists of:

1. Padding unit
2. Batcher or material handling system
3. Dye/alkali mixing device
4. A-frames, storage racks or storage boxes
5. Wash-off device (beam, beck, continuous, etc.)

Pad batch dyeing gives much lower defect levels than rope dyeing on many styles. For example, if dyed by exhaust methods on becks using direct dyes, fabrics of varying thickness, such as 100% rayon jacquard tablecloths, are difficult to process in rope form without streaking. Lower defect levels mean less redyeing, less use of stripping agents, etc.

Table 1.6.3-1  
Comparison of Annual Operation Cost

	Cold dyeing reactives on cotton pad/batch/L/2 beam wash-off stands	Conventional exhaust dyeing 100% cotton (19 becks)
Production (120 hr wk/ 50 wks/annum)	193,050 lbs/week or 9,652,500 lbs/annum	193,050 lbs/week or 9,652,500 lbs/annum
Labor costs	\$79,560	\$256,360
Fuel costs (Extra drying)	\$52,000 \$48,300	\$272,000
Water costs	\$ 8,700	\$ 98,500
Dye costs (Varies, see Table III)	-	-
Chemical costs		
salt		0
Alkali	<u>\$ 19,112</u>	<u>\$ 82,820</u>
	\$207,672	\$1,047,520

Table 1.6.3-2  
Capital Investment

Cost Comparison of Pad-Batch with Becks	
Pad batch dyeing system:	
Dye pad for knits 2 beam wash-off stands	\$160,000
Installation estimated to be 30% (includes pad entry, padder, 2 beam wash-off stands, dye/alkali pump, 10 beams, rotation stand, cradle let-off stray)	\$ 48,000 <hr/> \$208,000
Exhaust dyeing 100% cotton only:	
19 atmospheric becks 1000 pounds capacity each Cost - \$30,000 each Installation estimated to be 30%	\$570,000 \$171,000 <hr/> \$741,000

Table 1.6.3-3  
Typical Dye Cost for Pad-Batch vs. the Same Dyes on Becks [¢/pound)

Color	Pad-batch	Beck-dyed
Powder blue	30	40
Dark red	50	63
Bright yellow	35	50
Bright red	48	75
Bright blue	55	70
Light blue	37	58
Dark green	46	70
Navy	30	53

All the above costs are for dyeing only (for 100% cotton), not including preparation. All of the beck-dyed costs are cold reactive. In cases where the beck dye would be direct, pad-batch would probably cost more and beck dyeing will probably cost less.

The beauty of the pad batch system using the high reactivity dyes is that a great deal of the dye fixes in 30 minutes, and the difference in depth between one hour and eight hours is negligible in many shades. This is one reason for the unusual degree of shade reliability and is important because the fabric near the core of the take-up roll is obviously first on and last off, and has actually batched longer than the outer layers.

Because of the low physical affinity of these cold dyeing reactives, they work extremely well for all continuous operations that include a padding sequence. Color yield (exhaustion and fixation) tends to be lower when dyeing in a long liquor, compared to high affinity dyestuffs such as vats. A worthwhile increase in fixation can be accomplished in a shorter liquor, as the table below illustrates using a typical dye of the low substantivity group - in this case, CI Reactive Yellow 22.

Liquor-to-goods ratio L=	30:1	20:1	10:1	5:1	2:1	1:1	0.6: 1
% Dye fully fixed	20%	27%	40%	53%	68%	73%	75%
Increased color value using L ratio	265%	170%	82%	38%	7%	--	--

This contributes significantly to reduction of color in wastewater.

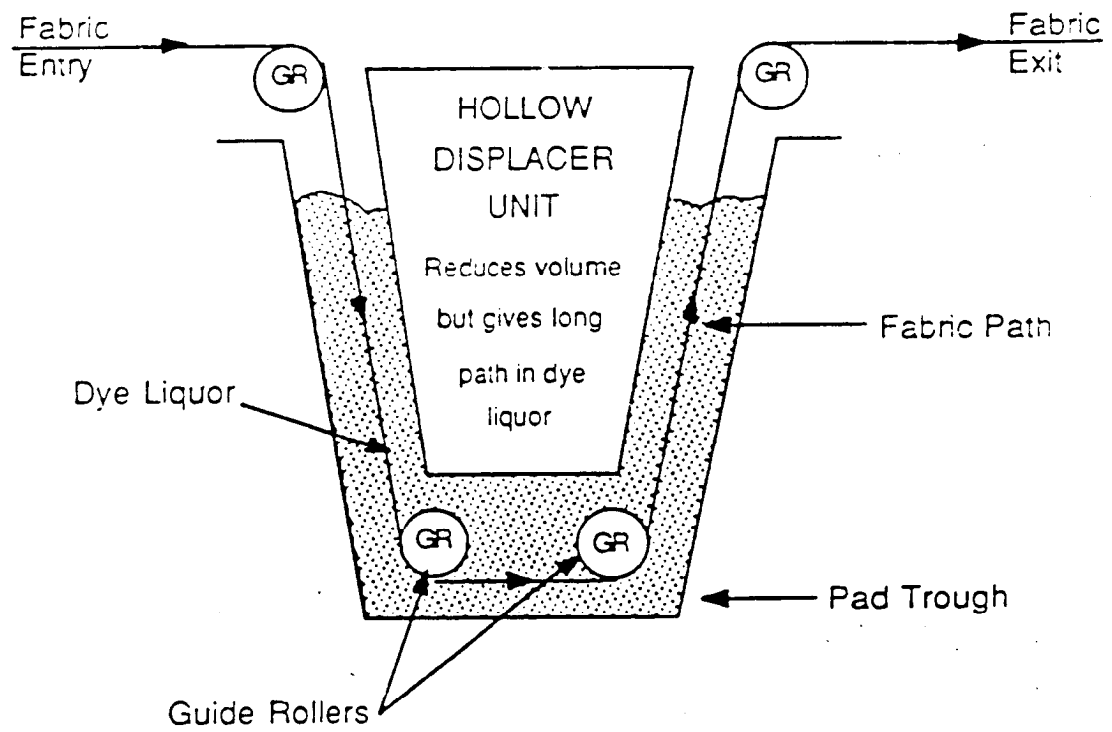
The advantages of this rapid fixation and stability of shade are obvious when compared to other methods. In jig and beck dyeing, for example, the normal routine is to continue dyeing, shading if necessary, until the correct color is obtained. Dyehouse operators are seen constantly cutting swatches off the goods for inspection. Even when the dyer is satisfied with the color, it may be that all fixable color has not reacted with the cloth, so that each batch must be treated individually. Highly colored wastewater and shade variations are inevitable. With pad batch, however, experience has shown that if padding and batching temperatures are properly controlled, reproducibility of shade is outstanding, and color in wastewater is reduced.

There is still another benefit of this rapid fixation. It is a minor point perhaps, and easily overlooked, but there is almost 100% reproducibility from lab to production shades. This means less time loss, dumped color, and fewer remakes. The pad batch system may be home design, but it must feature accurate mixing and metering. Two tanks hold dyestuff and alkali solutions which are fed to a mix and dispensing mechanism with a proportioning device. The mix is then fed via a pump to the pad unit. By employing a hollow displacer, it is possible to keep the passage through which the fabric passes less than one inch wide. This keeps the volume of liquor very low, about eight gallons or less, and insures the rapid turnover of liquor so that dye decomposition is kept to a minimum. This is, of course, important because adding the alkali to increase reactivity also affects the stability of the liquor. (See Figure 1.6.3-1

In working with plant production pad batch units, the following four point checklist has been helpful in avoiding problems:

1. Keep good alkali control by insuring adequate mixing and/or metering techniques.
2. Adjust exhaust dye recipes for pad batch by keeping accurate data on liquor ratios. Keep the immersion long, the liquor ratio short, and the volume low in the pad.
3. Have good preparation. Actually, pad batch reliability has reached the point where it can be used as a check on the preparation. If something doesn't look right, most often it can be traced to mistakes in preparation.

Figure I.6.3-1



PAD WITH DISPLACER

4. Keep good temperature control, and especially avoid dyeing hot fabric fresh from preparation. Feed cold fabric to the pad or else the temperature will rise. During very hot weather, keep the mix cool with a cooling water jacket, or use ice in the mix. In very cold weather, batch cloth in insulated boxes.

Since many mills that have agreements with municipal sewage systems pay on some formula based on the content of BOD, COD or other undesirable contents of the effluent, the pad batch method employing cold reactives is also attractive from the waste source management standpoint. Reactives do not require reducing or oxidizing agents, as do vats or sulfurs. Reactive dyes require using massive amounts of salt when employed in becks, but in the pad batch method, cold reactives require no salt at all.

The use of chemical specialties, such as lubricants, leveling agents, antimigrants, fixatives, defoamers and other specialties, by pad batch dyeing is usually not required. Small amounts of detergent are used in washing-off.

In summary, excellent results have been obtained with the pad batch (cold) system utilizing high reactivity dyes. Dyers have experienced many benefits:

1. Reduction in waste loads in effluent
2. Low capital outlay
3. Low energy requirements
4. High production speed
5. Reduced labor requirement
6. High color yield
7. Outstanding reproducibility
8. Excellent penetration, and leveling characteristics
9. Rapid fixation
10. Substantial overall cost savings (dyes, chemicals, labor, water, etc.)

At their inception in 1956, fiber reactives were noted for their exceptionally bright shades. However, the range has increased dramatically. The shade range now includes new dyes of muted tones aimed at shades that previously were considered the domain of direct, sulfur and vat dyes. Reactives have given a good account of themselves in terms of fastness and economy against traditional classes of dyes, and future prospects appear very bright indeed.

#### 1.6.4 **Foam Processing**

Processing solutions of textile chemicals can be diluted using air in place of part of the water by forming foams. There are several common commercial applications of foam processing, notably

- carpet dyeing,
- coating operations (backcoating),
- foam dyeing, and
- foam finishing.

The basic types are stable foam and unstable foam. Each requires a different chemical system and mechanical arrangement for producing, handling, and applying the foam. Use of these foam processing techniques can result in energy and cost savings, since there is less water to evaporate when drying the fabric. However, foam processing using continuous equipment (e.g. backcoating, dyeing) has the disadvantage that, when the production line stops, the foam must be disposed of. This can be very difficult, especially when stable foams (e.g. backcoating) get in the wastewater, producing hard to treat

suspended solids which will not settle. Possible ways to destroy excess foam include spraying it onto heated plates or dry cylinders where it can be rapidly dried, scraped off and recovered as a solid waste for landfill or other appropriate disposal. Prior to setting up a foam operation, it is important to plan for foam disposal by some method other than discharge to the process wastewater stream.

### 1.6.5 Recovery Systems

Many waste streams have recovery value, such as silver from photographic processing operations. Several common types of recovery systems are used by textile processors to reduce wastewater contamination and give economic benefits by saving raw material. Examples are

- water recovery (see Section 1.6.11,
- heat/energy recovery,
- caustic recovery, and
- size recovery.

#### 1.6.5(a) Heat/Energy Recovery

Most textile wet processors are familiar with some type of wastewater heat reclamation systems; however, the dollar savings is often not appreciated. The number of firms that still do not have reclamation systems that let existing ones lie inoperative for long periods of time is surprising, even though the less sophisticated laundry industry has been reaping savings for over 30 years.

#### Case History

A major carpet company installed an 800 GPM reclaim system before 1957. Operating this 48,000 GPH unit for the last 25 years (at a conservative 80 hours/week, 50 weeks/year, while raising the incoming average 55°F water to 100°F, at an average cost of 20 c/gallon for #2 fuel oil) saved the company over \$3.9 million. This on an approximate \$10,000 initial investment. At a current fuel cost of 95c/gal, this represents an annual savings of \$740,361. In addition, the savings in steam production is equivalent to more than 700 boiler horsepower.

There are several mechanical arrangements for heat recovery including “once through” and “stratified sumps” systems. Heat reclamation systems can be effected by fouling due to lint and other sediment which comes from processing of fibrous materials. Therefore, lint screens in dyeing machines, bar grates, and other primary control methods must be maintained to insure proper operation. Also, the design of the reclaiming itself can include anti-fouling features, such as timed backwashes.

Perhaps the easiest streams on which to practice heat reclamation are streams from washers and other continuous equipment. This can frequently be done without the complicated sumps, level controls, and other devices required for heat/energy recovery from waste streams.

#### Case History

Russell Corporation improved its conversion efficiency of steam from boilers to hot water for its bleachery by installing back pressure regulating valves to control return line condensate. This reduced the amount of condensate which flashed into steam and returned higher temperature condensate to the boiler. Each 10°F rise of boiler feedwater results in a 1% fuel savings. The total savings to Russell was \$1000 per day.



### 1.6.5(b) Size Recovery

Size represents the largest single group of chemicals used in the textile industry, which in most cases does not become a permanent part of the product. Therefore, size recovery represents perhaps the greatest opportunity for recovery of any chemical group. This is most convenient in vertically integrated mills where the recovered size can be returned directly to the slashing operation make-up kettles. The common types of sizes used on textile warp yarns are:

Starch	
Carboxymethyl cellulose (CMC)	
Polyvinyl alcohol	(PVOH)
Polyacrylic acid	(PAA)
Polyvinyl acetate	(PVAc)
Polyester	(PET)
Modified cellulose and starches	

By far the most common is starch. It is removed from textile substrates by the action of oxidizers, acids or enzymes. Because it is degraded, no recovery is possible. The other types are more or less recoverable. The molecular size, water solubility and other factors which influence recoverability are controlled by the molecular structure, particularly the molecular weight and substituents that are added to the polymeric chain. These substituents are used to control adhesion, film forming and penetration properties, removability, and other important features relating to the functional behavior of the size.

The recoverable sizes, primarily PVOH, are more expensive than starch. Thus it is difficult for a nonvertical weaver to use these more expensive sizes so that another independent processor can recover them at a later time. Also, it is difficult for a nonvertical wet processor to buy expensive recovery equipment in hopes that the weaver will use a recoverable size. Therefore, size recovery systems are found typically in vertical operations. A typical size recovery scheme is shown in Figure 1.6.5(b)-1.

Starch size can contribute up to 50% of the total BOD loading from processing of woven fabrics; thus there is frequently an economic incentive to switch from starch to the recoverable sizes to avoid BOD surcharges from POTWs.

Possible alternatives (for non-vertical processors) to the use of size recovery systems include using innovative desizing methods for starch. Starch is traditionally removed with amylase enzymes. Typically, about 60 lbs. of BOD per 1000 lbs. of fabric is produced by enzyme desizing of starch. Many companies are concerned about the BOD level of the chemicals that they buy; however, the combined chemicals that a typical textile mill buys accounts for no more than 20-25% of the total BOD pollution load being discharged. Textile mills that discharge their wastewater into a municipal or other publically owned treatment works, (POTS) must meet a specific BOD pretreatment limit, usually either 250 or 300 ppm in the wastewater. In many cases, the use of starch sizes on fabric can produce 200-300 ppm from this one source alone. The rest of the textile mill in total may produce another 200-300 ppm, giving a total of perhaps 500 ppm in the discharge. This is usually a violation of POTW pretreatment regulations. In order to alleviate this, many textile mills are forced to either build expensive pretreatment systems or switch to recoverable PVOH or CMC size. One other alternative to this problem is to desize the starch from the fabric with an oxidation system instead of an enzyme system. When the starch is degraded with enzyme, the result is anhydroglucose which has extremely high BOD. However, when the starch is degraded by oxidation using hydrogen peroxide, the BOD is much lower in the wastewater because the starch is degraded to CO<sub>2</sub> and water.

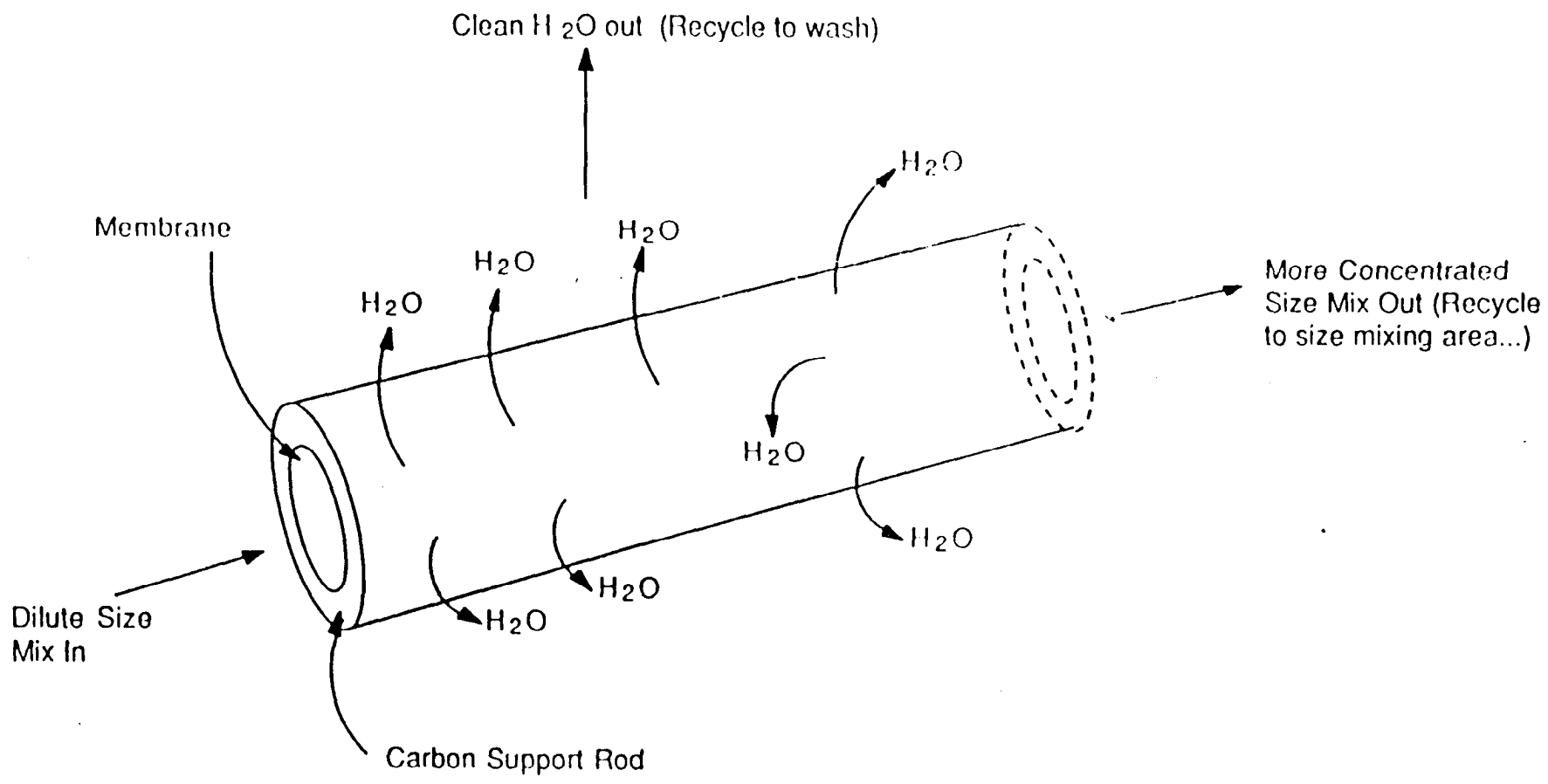


Figure 1.6.5(b)-1

Several companies now market equipment which is useful for this process. One approach is to use an open width desizing range which is very versatile and can be used for oxidation desizing or for enzyme desizing of starch. This open width preparation range, when used for oxidative desizing, will produce an effluent with very low BOD loading. In the future it is expected that processors, for example small printing plants which discharge into POTWs, will begin to use this oxidative desizing technology. This is not a new technology; however, it is not widely practiced due to the problems that can arise from oxidation damage of the cotton itself, producing oxycellulose. To carry out oxidation desizing successfully requires extremely careful control of temperatures, dwell time, and chemical concentrations. This has not been practical in the past due to the extremely close tolerances required; however, now with microprocessor-controlled chemical feeds and temperature and speed sensing equipment such as is present on newer open width preparation range, the necessary degree of control can be accomplished, and oxidation desize will begin to be accepted as a legitimate method of desizing.

Another innovative desizing method is the use of newer enzymes which have been developed for the home laundry market. Some of these degrade the size to ethanol instead of anhydroglucose. The ethanol can then be recovered by distillation for use as a solvent or fuel.

#### **I.6.5(c)Caustic Recovery**

Recovering of caustic from mercerizing operations is also practical. Mercerization is the process of treating cotton fabrics and certain blends with concentrated (20% or more) sodium hydroxide solution. Waste streams from this process are extremely alkaline. Because mercerization is always a continuous process, these waste streams are easy to segregate. Recovery systems can reclaim up to 98% of the caustic.

One system that avoids the caustic (and also water) use in the mercerization process is the use of liquid ammonia. This produces the same effect as mercerization, but without the highly alkaline wastewater stream. Of course, the ammonia gas is recovered and reused.

## **PART II - CHEMICAL AUDIT**

One critical step in solving waste problems through source reduction is auditing the **use of** chemicals and raw materials. The control of raw materials includes fiber, water, chemical specialties and commodities. There are a multitude of chemical specialty products which are used in wet processing, and they affect the amounts and types of waste produced. It is critical, therefore, to ensure that chemicals are of consistent quality. Simple methods for rapidly verifying consistency, as well as a protocol for prescreening, will be presented.

### **II.1 Chemical Specialties**

Chemical specialty “processing assistants” are used to varying degrees in textile processing. Some mills use enormous quantities of these materials while others use very little. Actual amounts used depend on mill-specific factors such as product type, quality goals, equipment, etc. The 1988 AATCC Buyer’s Guide lists about 5,000 chemical specialties in over 100 categories, offered for sale by about 175 companies with over 1800 trade names. (This does not include dyes.) The types of products offered run the gamut from acid specialties and adhesives to wetting agents and winding lubricants. Each wet processing operation makes a substantial investment in these products in terms of the cost of the product and, more importantly, in the risk involved with conversion of a greige substrate to a finished product. This economic risk of conversion is considerable and any loss of product from inappropriate use of chemical specialties can cut deeply into profit contributions.

Many components of these chemical specialty materials are discharged as waste or by-products from textile wet processing operation. They may be

- volatile, in which case they will become airborne (methanol, isopropanol, and trichlorobenzene),
- water soluble or dispersible in which case they will be discharged as pollutants in wastewater (copper, zinc, lead, surfactants), or
- insoluble or they may become part of a solid waste either in the wet processing operation or in the sludge (solid) waste resulting from the waste treatment system.

When evaluating chemicals for potential use, the ultimate “fate” of each should be determined and considered as part of the chemical evaluation procedure.

Some of the more common types of processing assistants include

- Preparation: Wetting, scouring (solvent and solvent-free), desize auxiliary, chelate, emulsifier;
- Dyeing: Dispersant, leveler, lubricant, emulsifier, wetters, retarder and accelerant, softener, compatibilizer, carrier, buffer, acid, alkali, antimigrant, defoamer, and
- Finishing: Antimigrant, resin, catalyst, softener, builder.

These products may vary in strength, quality, compatibility, and other properties in **such** a way as to cause product variation, unexpected product failure, and/or waste which may be hazardous, hard to treat, or excessive in quantity.

To set up a separate testing protocol for each chemical speciality would require extensive study, training, work and expense. Interpretation of data from such a wide variety of tests would be tedious. To avoid these complications, a simple and rapid testing protocol will be presented which can help a processor mill identify raw materials of questionable quality before damage occurs to in-process substrate.

These procedures are invaluable in waste management, especially hazardous waste management. An important part of waste management is raw material quality control. In many cases, undesirable wastes can result from raw material components and impurities which are not actually essential to the process, such as metal contents of certain dyestuffs or impurities in solvents.

## **II.2 Prescreening**

The first step in raw material quality control should include a chemical prescreening. Many companies have established an expert review group or committee to evaluate products in use or under consideration. Chemicals are evaluated according to a wide range of performance, health and environmental impact criteria. Duplicate inventory of similar products can be avoided using this procedure. The committee approach has proven to be an effective management initiative which has minimized hazardous waste production and the accompanying costs and environmental impacts. Just the cost savings from the reduction of hazardous waste production alone can provide a major economic savings to a company.

Such groups may include staff personnel, including a medical doctor, industrial hygienist, research chemist, professional engineer, corporate attorney, corporate safety officer, representative from chemical production, dyer, finisher, and/or information specialist.

Several criteria which should be used for evaluation include:

- cost and performance,
- hazardous waste characteristics (ignitability, toxicity, corrosivity, reactivity, flammability),
- priority pollutant status,
- availability of safer alternatives,
- biodegradability,
- heavy-metal content,
- potential for accumulation in the facility,
- potential for release to the environment,
- hazard potential when mixed with other chemicals,
- proposed manner of use,
- ultimate fate of the chemical,

- \* hazard potential to the customer,
- who will handle the chemical,
- how will it be used (mixed with, concentrations),
- does the user have the proper safety equipment,
- what are the spill procedures, incompatibilities, etc.

Screening chemicals in this way keeps costs lower by controlling chemicals at the point of use thereby reducing waste management costs. Also, nominal values for routine quality control checks of incoming shipments can be established. Safety and cost information can also be assembled and distributed at this time.

### **II.3 Quality Control of Shipments of Chemicals**

The subsequent quality control of all incoming shipments of chemical specialties can be performed using minimal equipment according to the following protocol. This procedure requires minimum effort on the mill's part and minimum expenses for testing and equipment.

A physical standard for each chemical product should be obtained from the vendor, as well as a technical product data sheet. This is usually part of the prescreening process discussed above. Several simple raw material tests should be performed on each drum or shipment of material as it is received or opened, It is necessary to move the chemical to a normal room temperature and allow it to acclimate before testing.

Prior to testing, retain an appropriate sized chemical sample (usually 100 ml) for future reference. In case of problems, this retained sample can be tested by more definitive and product-specific, performance-oriented tests. The tests listed below can then be performed on each drum or shipment. All data should be archived for later reference. In special cases, certain tests may not be appropriate; for example, the pH of organic solvents would not be meaningful data. However, most of these tests are useful for a wide variety of types of chemicals.

- Permanently mark the date that the drum was opened, as a visual verification that the test was done, and as an aid in detecting aged chemicals. An approval sticker is useful, with the date and technicians' "stamp of approval".
- Check pH with meter or paper.
- Check viscosity with Zahn cup.
- Check density with hydrometer.
- Visually note color and clarity.
- Note odor.
- Check index of refraction (for clear liquids).
- Compare data to previous history and vendors' standard values.

- Enter all date on control charts for display.
- Keep carefully documented records for each chemical on a long-term basis.

It is also a good idea to retest drums which have been opened for a long period of time.

By using these simple tests, a manufacturer can detect significant variations in products which are supplied to him for production use. Examples of the types of commonly occurring anomalies which can be detected are mislabeled drums or changes in the chemical formulation of a chemical speciality.

Chemical specialties are used in almost every textile operation and in most cases, the processor (dyer or finisher) does not know the actual chemical composition which he is using. Suppliers of chemical specialties do not reveal, and in some cases do not know, the composition of products they sell. In many cases, the composition of specialties can change without knowledge of the user or supplier.

The following case histories illustrate the effectiveness of this simple quality control method.

## **II.4 Case Histories**

### **Case History I**

A solvent scouring specialty, consisting of emulsified xylene was changed to chlorotoluene (for cost and labeling reasons) when xylene came under special restrictions imposed by the specialty manufacturer's insurance company. This had a great impact on the textile mill's air emissions from driers, becks, and storage tanks. This type of change would have been immediately detected as a change in density, index of refraction, and odor by the above testing protocol.

### **Case History II**

A vendor of disperse-dye carrier formulated a product from emulsifiers, solvents, and carrier-active, low-molecular-weight ester waste products from polyester manufacture. Because of cost and availability considerations, the vendor changed to a different polyester manufacturer for the carrier-active by-product but the chemical constitution was slightly different and, although the dyeing performance in the vendor's evaluation on 100% polyester was unchanged, the mill's processing of polyester/cotton blends was substantially affected. Many of the shades being processed on blends did not repeat. This type of change would also have been easily detected by the simple quality control tests described above.

### **Case History III**

A chemical vendor was reselling drum quantities of decyl alcohol ethoxylate wetting agents, which were being purchased in unlabeled drums. The vendor also had the same practice for cationic resinous fixative agents. He would simply stencil his own appropriate brand name on the drum and ship to his customer. The use of the wrong stencil caused the fixative to be labeled as wetting agent. When this mislabeled fixative was used in place of wetting agent in direct dyebaths, the result was disaster in the dyehouse. This could have been avoided by the previously described quality control tests.

## Using the Information

Results of each chemical tested by the above procedure should be reviewed with the vendor. It is important from the mill's point of view to let the vendors know that each and every drum and/or shipment will be tested and the results reported (even when they are good). It is generally not a good idea to wait until a defect is detected before reviewing the data with the vendor.

The former procedure establishes a rapport with the vendor before problems arise. Also, a vendor usually knows far more about the composition and quality of the material which he is selling than the customer does. The knowledge that the mill is checking can, in some cases, create a more quality-conscious attitude on the part of the vendor.

## II.5 Chemical Commodities

Chemical commodities used in large quantities in textile wet processing include electrolyte, alkali, acid, oxidizing and reducing agents, and others. For each of these commodities, the chemical identity is known; thus, testing is simpler and more specific than for specialties (for which the identity is unknown - usually a complex mixture of specialty products). Thus the methods of prescreening, testing shipments, etc. are somewhat different. Also, the substitution of chemical commodities is not as easy to do (as in the case of specialties) due to

- great cost impact due to large volumes,
- great product quality impact, due to widespread use (in many processes),
- great environmental impact due to large volume.

Also from a pollution reduction point of view, the impurities in commodity chemicals are very important. Commodities are frequently less refined than specialties, and thus may contain more impurities. Additionally, different sources (vendors) of a commodity may have differing amounts or types of impurities.

## E l e c t r o l y t e

Electrolytes are used in dyeing and, to a lesser extent, as desizing assistants. Usually one or more of the following is selected

- Common salt (NaCl),
- Salt brine (-20% NaCl solution),
- Glauber's Salt anhydrous ( $\text{Na}_2\text{SO}_4$ ),
- Glauber's Salt heptahydrate ( $\text{Na}_2\text{SO}_4 \cdot 7\text{H}_2\text{O}$ ),
- Glauber's Salt decahydrate ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ),
- Epsom Salt ( $\text{Mg SO}_4$  - rarely used).

A reasonable quality control scheme for these materials consists of testing for

- 1) acid or alkali content by pH and alkalinity of a 10% solution,
- 2) insoluble material, by filtration,



- 3) cleanliness (trash), by visual inspection,
- 4)  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$ , by standard methods of analysis,
- 5) iron, copper, manganese and other heavy metals, by methods of water analysis, or
- 6) organic-extractable materials.

### **Alkali/Acid**

Alkali materials are commonly used in preparation and dyeing processes including caustic (50% NaOH solution), soda ash ( $\text{Na}_2\text{CO}_3$ ), bicarb ( $\text{NaHCO}_3$ ), ammonia ( $\text{NH}_3$  solution), TSP ( $\text{Na}^3\text{PO}^4$ ), silicate, TSPP, and others.

Methods for analysis of these materials generally involve titration with standard acid. After neutralization, it is possible to measure the metallic contamination by standard water analysis methods .

Several types of acids are widely used, including hydrochloric, sulfuric, phosphoric, minerals salts MSP (monosodium phosphate), acetic, formic, and oxalic. The general assay procedure for these is to titrate with standard alkali using standard procedures. The contribution of acids and alkali to pollution is mainly in the area of pH and metallic impurities. Since textile processes have specific pH requirements based on the technical requirements of the process, it is not generally possible to reduce the amounts used. However, some techniques can help with acid/alkali problems. These techniques include:

- mixing of acid and alkali streams,
- neutralization at the point of discharge,
- reuse of acid/alkali materials,
- recovery (caustic).

### **Oxidizing Agents**

Common oxidizing agents used in textile wet processing include; peroxide (hydrogen peroxide), bleach (hypochlorite, bleaching powder, chlorine, etc.), chlorite (Textone®, sodium chlorite), perborate, permanganate, dichromate, periodate, and bromate. These are generally analyzed by redox titration. Methods for analyzing specific chemicals are given in *Analytical Methods for a Textile Laboratory*, which is published by AATCC, Research Triangle Park, NC. The table below summarizes these procedures. Here again, the metallic contamination is a potential pollutant source.

**Table I: Titrations**

Oxidizer	React with	Titrant	Indicator
Peroxide	-	permanganate	Pink color of excess permanagante
Hypochlorite	arsenite	iodine	Starch/iodine complex
Chlorite	iodine	thiosulfate	Starch/iodine complex
Perborate	iodine	thiosulfate	Starch/iodine complex

### Reducing Agents

Reducing agents are used widely in dyeing processes and to a lesser extent in preparation (bleaching). They are also used for removing surface dye from fabric (after-clearing) and from dyeing machines. In addition, they are used as “antichlor” agents to destroy residual chlorine from hypochlorite, chlorite bleaching or stripping prior to a dyeing process which uses potentially chlorine-sensitive dyes.

Common reducing agents including hydro ( $\text{Na}_2\text{S}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ), thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ), sulfoxylate/formaldehyde adducts (Parolite®, Discolite®) are analyzed by standard redox titration methods.

Methods for analyzing other reducing agents are similar, but sometimes include direct iodometric titration or reaction with excess oxidizer followed by back titration.

### General/Other

Other chemical commodities which are widely used, include size materials, chelates, enzyme, and surfactants. Size materials can be analyzed rapidly by spot tests (see C. Livengood; *Textile Industries*, September, 1983, p. 114) or by more sophisticated procedures (see P. Seydell, *Textile Warp Sizing*, Phoenix Printing, 1981). The type of size material in use has a great impact on BOD levels in wastewater. For knits, the selection of winding emulsion and knitting oil has a great impact on BOD. Surfactant selection is crucial to aquatic toxicity and BOD. This is discussed in another section of this handbook.

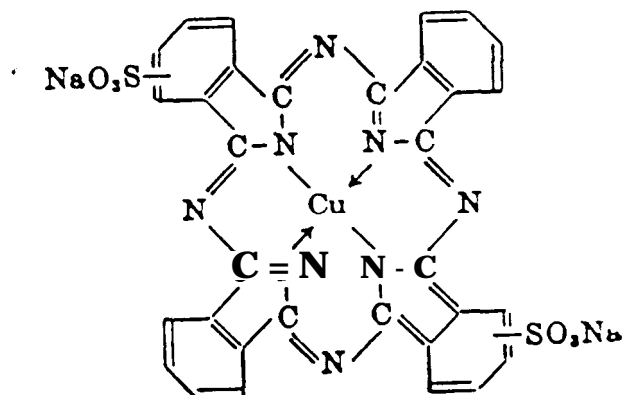
## **II.6 Audit Procedures**

There are several information sources which should be utilized in a wet processing chemical audit:

- physical inventory,
- purchasing records,
- processing formula/recipe sheets,
- production records (by machine, process, or department),
- waste production records,

These can be analyzed in several ways, one of which is “mass balance” (see the example below). However, a word of caution is in order about using mass balance for auditing chemical waste. In the case of large chemical input and large product output being balanced, the difference in terms of a small waste stream generated may be very uncertain. For example, to estimate how much copper is contributed to effluent by using 2% of CI Direct Blue 86, the following calculation is exemplary.

**74180 C.I Direct Blue 86** (Bright greenish blue)



(Sulfonic acid groups in the 3-positions)

Suppose this dye (commercially) is 8+/- 1% copper, and exhausts 87+/- 3% from the dyebath. Furthermore, suppose that 1000 pounds per day of fabric are dyed with this recipe. How much copper will this source contribute to the mill effluent ?

- Amount of dye used is 2% of 1000 pounds or 20 pounds
- Amount of copper is 8+/- 1% of 20 pounds or 1.6+/- .2 pounds
- Amount of copper discharged is 13+/- 3% of 1.6 +/- .2 pounds or .21+/- .07 pounds

Thus errors of +/- 1% and +/- 3% in the audit information for copper content and exhaust level, respectively, contribute to an uncertainty of 50% (+/- 25%) in the mass balance estimate of copper discharge. This kind of situation is not at all unusual when estimating small waste amounts from the difference of large raw material inputs and product outputs.

Another factor to keep in mind is that a substantial portion of the waste load from textile wet processing results from non-process sources. It is important not to ignore these non-process sources which can be up to 50% of total waste loads. Some non-process sources include

- rinse of dispensing equipment,
- cleaning of process equipment (residues as well as cleaning chemicals),
- dumping unused processing solution,
- shop chemicals and other non-process sources, and
- drum washes, parts cleaner (e.g. print screens).

All of these potential sources must be included in the audit.

Using several sources of data (as listed above) can give several ways of estimating the waste resulting from a given chemical. It is also important to include potential pollutants which are part of the substrate (yarn, fiber, fabric). Knitting oils, warp sizes and fiber finishes are particularly large contributors.

## **PART III - MECHANICAL AUDIT**

Although the primary emphasis of this document deals with chemicals and processes, significant source reductions can be made through mechanical means also. Three aspects will be discussed here:

- (1) Housekeeping
- (2) Mechanical Audit
- (3) New Equipment

Many mechanical examples are discussed in other sections of this workbook, but the above are discussed here as separate items because they represent broadly applicable principles and because they represent illustrations of equipment innovations which are useful for source reduction.

### **III.1 House Keeping**

It may seem very simple, but housekeeping and work habits of chemical mixers can account for 10% to 50% of a mill's total effluent load in certain parameters, such as BOD, COD, metals, and organic solvents. Certainly a mill with pollution problems should, as a first step, review all possible remedies. Improvements in housekeeping generally have little or no cost, improve employee morale, and make for a generally better workplace and better quality and safety. Spilled chemicals, dirty floors with metal shavings, etc., being swept into drains, sloppy mixing practice, spillage and other disorderly situations are frequently major contributors to waste loads, as well as safety hazards.

### **III.2 Mechanical Audit**

Maintaining equipment in its optimum mechanical condition is critical to producing high quality products and reducing extensive waste. It is not unusual to see processing baths being lost down the drain by leaking drain valves or "drag-out". One example is print paste which is doctored off of roller print machines. This can be captured instead of being allowed to drip and accumulate in drains. It can then be reused to achieve reduction in suspended solids in effluent.

Another example of mechanical oversight which can lead to increased waste load is improper level control in batch dyeing in equipment such as becks. If the liquor ratio is inadvertently increased, either for mechanical (level control failure *or* leaking fill valve) *or* supervisory reasons, more chemicals will be required, dye fixation will be less (resulting in more color in the wastewater), and more wastewater (hydraulic load) will be produced.

It would be impractical to write an audit procedure for every type of wet processing equipment; however, the following will be presented as an example of an audit procedure. Similar procedures for all equipment *in* a wet processing operation can significantly decrease reworks, off quality work, and resulting pollutants.

### Equipment Audit-Example: Becks

Becks are one of the oldest traditional types of equipment for exhaust dyeing. Their continued popularity indicates the versatility and economy of becks. They provide quite a lot of mechanical action to the fabric. Older models, which generally lack heat exchangers and circulating pumps, frequently have problems with temperature differentials (front-to-back, end-to-end) as well as the difficulties associated with the use of live steam. These machines cannot be heated properly unless they contain cloth. Therefore, any attempt to heat prior to loading the fabric is futile and a waste of energy (steam).

Since the electrolyte and alkali are to be used on the basis of bath volume, it is important to know and control the exact amount of dye liquor in the beck. This can be determined either with a water meter or by the use of commonly available tables. An audit checklist for mechanical condition of becks is presented in Table 111.2-1. An operations checklist for becks is shown in Table 111.2-2. Careful attention to these details through audit procedures such as those shown in the tables will improve the *efficiency* of almost any *process*. These audits should be done at least once a week for most equipment. An uncorrected mechanical problem creates very bad attitudes among machine operators. These mechanical problems cause waste, pollution, and off quality work if uncorrected. Thus mechanical audit procedures are very important.

**Table III.2-1**

#### **Beck Audit - Mechanical Inspection**

Reel type, shape, cover, speed - compatible with substrate and dye recipe

Idler reel - turns free and true

'Snags' or rough edges in the machine

Tangle detector - rake and reel overload

Tangle alarm - audible and visible

Controller accuracy - temperature and rate of rise

Leaking valves - drain, fill, steam types

Steam quality available (while other demands are "on")

Circulating pump and heat exchanger (if any) - performance at operating temperature

Location and integrity of temperature sensor

Location and evenness of steam injection for heating

When heating and also when holding at 140<sup>0</sup> and 200<sup>0</sup>F, front-to-back and end-to-end temperature differences

Overhead steam (if any)

Damper and door (front and rear) operation

Verify damper ability to exhaust fumes

Fill water temperature

**Table III.2-2**

**Reck Operations Checklist**

Load out the entire length.

Load size - 60 to 80 pounds per beck root (typical).

Long strands dye light, short strands dye dark, be sure all the strands are the same length.

Load out fully and evenly.

Sew seams straight, no twist in strands, no holes in seam.

Control the liquor level according to the fabric; too high gives tangles and “swimming” of cloth, too low gives abrasion, streaks, blotch dyeing.

Schedule light shades first, dark shades later.

Base electrolyte and buffer on the bath, not the cloth.

Ensure moderate ballooning by allowing some foam or air to collect inside tubular goods - inflate with air hose if needed.

Be sure to take a slow rate of rise near the critical points, such as wet Tg and dye strike temperature.

Don't boil a beck - tangles will result.

Use overhead steam to prevent drips - especially in winter.

Be sure doors and dampers are closed when running at high temperature to avoid cracks and drips.

Be sure goods have adequate turnover rate - once per minute is typical.

### **III.3 New Equipment**

Textile equipment manufacturers are becoming more and more aware of the need to conserve water, chemicals, and energy. In fact, many new machine technologies have been, at least in part spawned by that awareness. The following sections describe some of the best present technology, with a look toward the future of textile wet processing.

#### **Bleaching Equipment**

New types of rope bleaching units introduced in the late 70's typically produce 40 pounds per minute of knit fabric, or over 1 million pounds per month on a three-shift six-day operation. They have become very popular with large knit processors due to their flexibility and conservation of energy, water and chemicals. These units are being promoted now for use in afterwashing fiber reactive and other types of dyes, in addition to their normal uses and preparation equipment. However, some of the first models had mechanical problems which are being improved by several new innovations. Typically, these machines are microprocessor-controlled, and each compartment has individually controlled temperature, chemical feed, fabric transport and counter current water flow. Each compartment also has dual automatic chemical feeds and features high efficiency filters to prevent accumulation of lint and sediment which has been a substantial problem in the early model machines. The reason for precipitation of the bleach bath is fairly complex, but the fundamental cause is the reluctance of knitters to use silicate stabilizers for peroxide bleaching. Other types of stabilizers include specialty chemicals composed of sequesterant DTPA, oxalates, epsom salts, phosphates, and certain types of dispersing agents that are less effective than silicate. Because of this, bleachers of knit fabrics sometimes add excessive amounts of peroxide which tend to decompose and produce foam in the machine. The foaming tends to produce more lint, tangling, and other transport problems. Therefore, defoamer is frequently added. Defoamer further destabilizes the bath, producing more precipitates and residue in the machine. Systems of high efficiency filters to remove these materials produce a better running machine. This equipment also features overhead duct work exhaust systems to remove fumes.

In early model equipment, fabric was transported from one compartment to another by the use of jet tubes to assist the movement of fabric. Inflated rubber lifter rolls, which resembled small automobile tires, were used to pick up the fabric and feed it into the jet tube for transport to the next section. One problem with these early machines was occasional loss of air pressure in the lifter roll. In other words, the machine simply had a flat tire. The new machines solve this problem by using foam-filled lifter rolls which can not go flat, eliminating one of the maintenance problems with the original machines. Another problem that plagued the older machines was uneven fabric transport. As mentioned earlier; the use of non-silicate stabilizers can lead to substantial foaming in the bath. This produces, in many cases, extensive ballooning of the knit fabric and causes it to choke the jet transport tube and slow down the fabric flow.

Newer models employ unique systems of automated sensing equipment to detect how much fabric is in each compartment. This is detected by a plunger-activated sensor which feeds information back to the microprocessor computer control. The microprocessor then adjusts the operation of the machine to compensate and avoid uneven dwell time. Without this compensation, more fabric accumulates in one chamber of the machine and less fabric in another, causing variations in the bleaching efficiencies, whiteness, absorbancy, ash content, and other properties of fabric. For example, a fabric which had too much dwell time in the tinting section would pick up too much of the tint, therefore giving an off-shade condition. The machines avoid uneven dwell times by sensing how much fabric is in each section, feeding the information back to a supervisory microprocessor control system and then maintaining appropriate jet pressure, lifter roll speed, chemical feed, and counter current water flow. This gives very efficient and even bleaching action.

A “problem” with the original machines has been the high productivity of the machine itself. For the small textile mill, the extremely high productivity of these machines means that the preparation machine will need to run for perhaps only two or three shifts per week. But there are now smaller machines called compact bleach ranges which are miniature versions of the original machines. They have a production capacity of only 60,000-80,000 pounds per week for bleaching, and they can also be used as a wash-off unit for pad batch-dyed goods a rapidly increasing dyeing technology. This reduced capacity keeps an even balance of production in a small dyehouse between the preparation and the dyeing departments.

These machines have an inherent counter current water flow design, and can be generated with little over-flow of wastewater. This reduces substantially the primary waste problem of cotton preparation, which is high volume waste streams of high pH and alkalinity. Energy and steam use is less, resulting in less air pollution from boilers. Also the high efficiency filters allow for dry capture of suspended solids, allowing for more efficient disposal by landfill. With the improvements which have been made in these machines, they can be an important part of a mill’s waste management program.

### **Vacuum Extraction**

Several companies have recently introduced new equipment which employs vacuum technology. These machines can reduce drag-out and carry-over of chemical solutions with cloth, which results in undesirable downstream contamination of processing baths and reduces washing efficiencies. One manufacturer recently presented case histories of actual production situations in which a processor had installed vacuum slots after each wash box in one of their existing lines, and was able to reduce the number of boxes from eight to three. Complete wash boxes with built in vacuum extractors were available for the first time last year. There are also washers for prints which combine successive spray and vacuum slots without a bath or trough for the fabric to pass through. Since the fabric is never in contact with a liquid bath, bleeding, marking off, and staining of grounds is minimized, and water usage is reduced.

Another interesting bathless washer which is useful for the afterwashing of prints is a new vertical counter-flow washer, in which the recirculated water is sprayed on the fabric and squeezed through the fabric by the rollers into a sump, where it is filtered and recirculated. The filter is unique, consisting of continuous loops of polyester fabric. The wash liquor is sprayed on the fabric and is filtered by gravity flow. The filter fabric rotates continuously and is cleaned of filtrate at one end by a hand spray of clean water. This allows for maximum removal of suspended solids from water prior to discharge and high efficiency washing with low water usage. Energy use is reduced greatly, since less water must be heated.

### **Conventional Extraction**

Great energy savings can be made by mechanical removal of water from textiles, rather than by evaporation. Techniques include centrifugal extractors of the basket type and vacuum systems. Basket extractors are nothing new; however, it is interesting to see so many unique new configurations being produced by equipment manufacturers. Usually a system like this would not merit mention simply because the technology is so old that everyone knows what basket extractors are, what they do, and how they work. However, manufacturers are now putting some new wrinkles in this technology such as centrifugal extractors with interchangeable baskets. The baskets can be rapidly removed or replaced and changed over between stock extraction, yarn extraction, etc. Some of them are configured in such a way that yarn packages of different sizes can be accommodated. Others are designed for yarn in skein form, and still others are configured for drying or extracting stock or for extracting fabric in different configurations. Advantages in terms of waste management are the same as for vacuum extraction (above).



### **Package Dyeing Equipment**

In the area of package dye machines, there are a few nice innovations, like single package simple kiers mounted on the side of the package machine. This single package kier allows for shade judgments to be made without opening up the main body of the machine and removing packages. This means that a more rapid assessment of the dye shade can be made by an operator without disturbing the main load of the machine. This in turn means that dye adds can be made more quickly, allowing the dyes to add in the original dyebath. The current practice used in many package dye operations is to run each dye procedure straight through, making shade adjustments in a separate, new dyeing. This produces extra wastewater and chemical discharge. This is usually done due to time constraints. Thus these single package sample kiers facilitate on-line adds, effluent volume reduction, and chemical waste reduction.

Another innovation for package dyeing equipment is controllers which sense and regulate the inside/outside or outside/inside pressure differential across packages as they are being dyed. Because of variations in fiber properties, winder efficiency, shrinkage of packages, compression, etc., different types of yarn are most efficiently dyed at different flow rates and different pressure differentials. If the pressure is too high in a package dye machine, channeling and blown packages can result. If the pressure is too low, bullseyes, poor penetration and others defects result. A package dye machine which has this inside/outside pressure differential controller has the ability to handle more different types of yarn successfully, and is therefore a more versatile dyeing machine. Of course, all of the newer package dye machines feature extremely sophisticated microprocessor controllers. Package dyeing is one situation in which the microprocessor controller shows an excellent return on an investment simply because it is possible to do so many dyeings that are very close to the standard if the control is proper. Such controls reduce reworks, overdyes, and remakes, thus reducing pollutant loads. Also, optimization of processes leads to waste reduction through more efficient chemical use.

### **Dye Machine Controllers**

Perhaps the most significant current trend in dyeing is the development and utilization of dye process controllers both for batch and continuous dyeing. Many companies now in this market do not sell dyeing machines, finishing machines, preparation, or any other kind of textile processing machines. They strictly sell controllers. In most cases, these are single-board microprocessor controllers. In some, programs are provided through an operator key pad entry or through a microcassette drive, while in others programs are set in firmware and are changeable by substituting EPROMS or other firmware. The most significant fact, however, is the marketing of universal multi-purpose flexible controllers to automate essentially any machine in the market. This means that many of the machines now in mills can be retrofitted with microprocessor controllers. These are, in many cases, 32 or 64 channel sensing devices with feedback control loops which can sense and control pH, color, temperature, conductivity, flow rates, and mechanical events such as opening or closing of doors, dampers, valves, etc. Feedback loops can be used to control steam valves, pumps, chemical feed systems, dye dispensing systems, etc. This technology will have a massive impact on the United States textile industry within the next 10 years. For example, at the ITMA '87 Equipment Show, 99 companies exhibited dye equipment, while 125 exhibited controllers. In many cases a controller/ microprocessor company will join together with another that has knowledge of dye dispensing systems, metering systems, chemical feeds systems, pumps, valves, control circuitry, interfacing, feedback loops, and firmware, with the result being a microprocessor control system. Often these companies begin by offering these microprocessor control systems for their own equipment and then branch out with subsidiary or independent companies in such a way that they offer the textile control system as a stand-alone unit.

### **Automated Chemical Systems**

A related area is the automated drug room and automated dye dispensing systems. Automated chemical and dye dispensing systems are going to be one of the big innovations of the

next 5-10 years for the textile dyeing industry in the United States. Handling chemicals by human workers is hazardous, inaccurate, nonreproducible, wasteful, and expensive. Wet processors must meet the following four basic requirements in the future: (1) flexibility required by running smaller lots, faster delivery times, better lab to dyehouse correlation, and a wider variety of styles; (2) higher quality; (3) minimum waste and pollution; and (4) lower cost. Dyehouse and drug room automation can directly impact each of these areas. For example, dye ranges can be automated so that either liquid or power dyes can be fed directly to the machine. This control means fewer errors from weighing, fewer safety problems from handling, and better repeatability for lab to dyehouse correlation. Dyehouse automation can also interface nicely with quality control of raw materials. For example, if a dye is found to be too strong or too weak, an automated system **can** simply be programmed to compensate by dispensing adjusted amounts to get the correct shade. The same advantage exists for chemicals. In the automated drug room, transport, handling, **and** storage can be automated through the use of robotics. It has been estimated that the cost for handling, storage, and transport of dyes and chemicals in a mill may account for up to 10% of the total cost associated with the dyes and chemicals.

Using automated dispensing equipment is also a much more accurate method of producing lab dyeings than the traditional pipet method used in most textile operations. Several studies indicate that dye accuracy of better than 1/2% can be obtained this way, compared to 2 to 5% errors for human workers using pipets, so this equipment also holds great promise in terms of reproducibility of shade and reducing waste. For example, in a continuous dye range or printing operation, it is an extremely unfortunate situation when a dye mix or print paste runs out. In that case, more must be made up and the chances of making up two batches of dye or print paste which are precisely the same using human methods is not good. However, with automated dispensing systems, the amount of required print paste can be calculated, measured and prepared more accurately, and if the print paste or dye mix should run out, there is a much better chance of getting an acceptable replacement or additional mix made up. This means better shade reproducibility as well as less waste, solution dumps, and cost associated with the waste. In some cases these systems are being interfaced with computer color match systems. In the future, optimization of dye recipes and procedures may be done "on the fly" by automated dispensing systems and artificial intelligence coupled with an on-line spectrophotometer. At North Carolina State, research is now underway for exactly such systems using artificial intelligence as a basis for the feedback control of such automated dyeing machines and drug rooms. One key to accomplishing this is to have accurate dispensing systems which will meter given amounts of dyes and chemicals and feed them into machines at predetermined rates.

For example, in fiber reactive dyeing, alkali added all at one time will produce a rapid exhaust of dye onto the fabric and reaction. Alkali, if added in small discrete quantities will produce a series of such rapid strikes of dyes onto the fabric. However, a continual and appropriately controlled addition of alkali can cause a smooth and even exhaustion of dye onto the fabric. In this way, alkali addition can be optimized. The same thing holds for the addition of the dyestuff itself, salt and other chemical auxiliaries. Similar kinds of systems are available for making print paste automatically. These systems deliver print paste from overhead tanks, automatically dispense into a print paste tank, mix and homogenize, and then deliver to the mix tank for use on the print machine. This system is applicable to printing or continuous dyeing and has spigots for drawing off color manually.

### **New Dyeing Machines**

One type of new dyeing technology, continuous dyeing of knits, offers substantial source reduction of waste due to its inherent nature. Another section of this document covers in detail the pad-batch method for fiber reactives. But there are also systems for other dye classes. Continuous tubular dye ranges for cotton knits were developed primarily for reactive dyeing by the pad-steam method. Continuous dyeing uses substantially less water and dye auxiliary chemicals than batch methods; also chemical use is decreased, resulting in fewer problems from chemical **wastes**.

## **PART IV - CASE HISTORIES**

There have been numerous case histories presented in Section I and II, and several more are presented below.

### **IV. 1**

Company: Rexham Corporation

Location: City of Matthews (Mecklenburg County)

Product: Paper, Film and Foil Products

Description: Rexham has developed a comprehensive waste management program incorporating several managerial and technical initiatives to reduce waste generation. For example, waste toluene from printing press cleanup has been eliminated by segregating the solvent according to the color and type of ink cleaned from the press. Each segregated batch of toluene is then reused for thinning the same type and color of ink. A carbon adsorption recovery system on the printing lines allows Rexham to capture and recover 90% of the toluene previously lost to the atmosphere. The recovered toluene is sold to the coating industry for use as a thinner at about one half the price of virgin solvent. Another major solvent waste stream containing methyl ethyl ketone is sent off-site for recovery and then reused by Rexham for cleanup operations.

Savings: Rexham's waste management program has reduced waste management cost as well as production costs. The sale of over 4500 tons per year of toluene captured by the carbon adsorption system realized a small financial return of 1 to 1 1/2%. The reuse of the waste toluene cleaning solvent reduced raw material costs and eliminated the cost of disposing of this waste stream.

### **IV. 2**

#### Printing Inks

Company: Thiele-Engdahl, Inc.

Location: City of Winston-Salem (Forsyth County)

Product: Printing Inks

Description: Thiele-Engdahl recovers and reuses spent isopropyl acetate generated during equipment cleanup. Solvent is used twice for equipment cleanup before being recovered. The solvent is reclaimed on-site using a batch distillation unit. The distillation system processes two 55-gallon batches every 24 hours. The distillation bottoms are sent off-site for disposal.

Savings: Before the distillation system was installed, Thiele-Engdahl sent about 5,000 gallons of spent solvent off-site for disposal every 45 days. Reclaiming and reusing the solvents on-site significantly reduced this volume as well as the quantity of virgin solvents purchased. The savings are projected to fully cover costs for the distillation systems in 2 years.

### **IV. 3**

Company: United Piece Dye Works

Location: City of Edenton (Chowan County)

Product: Textile Dye and Finishing

Description: United Piece Dye Works met stringent effluent discharge limits on phosphorous by making chemical substitutions in their production process rather than by building expensive treatment systems. A detailed evaluation of production processes, process chemistry, and the chemicals used identified sources of phosphorous. Process modifications to reduce use of phosphate chemicals and substitution of non-phosphate containing chemicals were made. For example, the use of hexametaphosphate was reduced and the use of phosphoric acid was eliminated. A reduction in the level of phosphorus in the effluent from 7.7 mg/L to less than 1 mg/L was achieved through such modifications and chemical substitutions.

Savings: United Piece Dye Works met their effluent limits without any capital expenditure for phosphorus removal.

### **IV. 4**

#### Synthetic Fibers

Company: Celanese Corporation

Location: City of Greenville, South Carolina

Product: Synthetic Fiber

Description: Celanese recovers and reuses two of its waste streams. Freon, used in the quality control laboratory, is recovered for reuse by a glassware batch distillation system. The still recovers most of the 4 gallons of waste solvent generated each week. Contaminated heat transfer fluid (Dowtherm) is sent to an off-site distillation facility for recovery and returned for reuse in production. Similar pollution prevention methods are used at Celanese plants in Salisbury and Shelby.

Savings: The recovery and reuse of Freon in the laboratory saves Celanese's Greenville plant over \$1,800 a year in disposal and raw material costs. Recycling of heat recovery fluid saves the plant about \$164,000 per year in disposal and raw material costs. Similar cost savings are realized by Celanese's two plants in North Carolina.

#### **IV. 5**

Company: American Enka

Location: Enka, NC

Product: Synthetic Fibers

Description: American Enka Company is a nylon yarn production and research facility. One of their processes uses isopropyl alcohol as a solvent for a fatty amine. The end product is a porous film of polymer. They previously employed an outside firm to distill their waste isopropyl alcohol. They then bought it back for reuse in their production line. Average distillation losses were 15%, but losses as high as 40% had occurred. Also, due to improper cleaning of the distillation column between runs, the isopropyl alcohol returned was often unusable due to contamination with Dowtherm, benzene, ethyl benzene, methyl benzene, various chlorinated hydrocarbons, and other organic constituents. Each batch of recycled isopropyl alcohol had to be analyzed for contamination, and, if found unsuitable, required disposal arrangements and fees.

Savings: To solve this problem, American Enka purchased a used distillation unit for \$7500 and modified it to redistill the isopropyl alcohol in-house. This resulted in a savings of \$90,000/year, since it is less expensive to distill the alcohol on-site than to contract out these services. In addition, the in-house distillation is more efficient, recovering 90% of the isopropyl alcohol as opposed to the outside firm's efficiency of 85%. Not only does American Enka reuse the pure isopropyl alcohol the distillation unit produces, but they also utilize the still bottoms as an asphalt emulsifier in another product line. The payback period for this project was approximately one month.

#### **IV. 6**

Company: Ellen Knitting Mills

Location: Spruce Pine, NC

Product: Knit Fabric

Description: Ellen Knitting Mills, a Division of Hampshire Hosiery, was discharging spent dye bath water to the municipal sewer system. The temperature of the discharge water was 130 degrees F, which caused breakage of the terra cotta sewer piping. In 1981, the company invested \$100,000 in a heat exchange system that lowered the effluent water temperature to 70 degrees F. Spent dye water is discharged into a holding vat from which it enters the stainless steel heat exchanger. The exchanger is composed of five 30-foot long 8-inch diameter pipes. Inside each pipe is a bundle of smaller tubes which allow the heat transfer.

Heat removed from the water is used to preheat incoming feed water for the dye tubs from 55 degrees F to about 105 degrees F. The preheating operation saves about 52,000 gallons of fuel oil per year, and the heat exchange system had a payback period of only two years.

The company made a second major modification which has also resulted in significant energy savings and reuse of waste materials. In 1982 Ellen Mills purchased and installed a sawdust fired steam generating plant for approximately \$800,000. The units consists of a 12 ton receiving hopper, a conveyor transport system, a hogger, a 200 ton storage silo, a dutch oven combustion chamber, an auxiliary oil burner, and a 400 horse power HRT boiler..

In the vicinity of Spruce Pine, North Carolina, there are several local sawmills and a ready supply of wastesawdust. The sawdust is trucked to the mill, where it is dumped into the receiving hopper, passed by conveyor belt under a magnet to remove metals, and passed on to a hopper where it is ground to a uniform size. The sawdust is then lifted by a bucket elevator to the top of the storage silo, which holds an 8 day supply of fuel.

Sawdust exits the silo from the bottom, where it is collected in a metering bin which dispenses it to a screw conveyor leading to the boiler. The metering bin has sensing devices to monitor the steam pressure in the boiler and releases sawdust as needed to maintain a constant pressure. The measured charge of sawdust is blown into the dutch oven where combustion takes place. The heat produced by this combustion is introduced into the boiler where the steam is generated.

The exhaust gases pass through a series of cyclone separators to remove any particles and then into a smoke stack. At this point, a heat exchanger transfers heat from the exhaust and reinjects it under the grate in the combustion chamber. Since the mill has ample capacity in their dye house heat exchanger, they are using the preheated water as their boiler makeup water. This results in greater energy efficiency for the system.

Savings:

The new boiler system has eliminated the need for 300,000 gallons/yr of fuel oil. The sawdust fuel costs approximately \$12.00/tan; the company reports a 66% savings on fuel costs. They estimate a payback period of only 4 years for the new system. The new boiler is also a much cleaner system since it is equipped with state-of-the-art pollution control devices. Cyclon separators scrub the vapors and prevent the particulate "fallout" that was present with the oil-fired steam generator.

## **PART V - CONCLUSION**

This document presents some ideas which have been used, or can be used, to reduce pollution sources and accomplish cost reduction or economic advantage at the same time. Unfortunately, the material presented here is limited because of two reasons. First, the scope of this document did not permit all possible avenues to be fully explored. Second, almost all methods of source reduction are site-specific; thus, it is not possible to cover every situation in a generic way. However, the material presented here, along with the conference proceedings, can lead to innovations and ideas which can result in cost savings and source reduction of pollutants in textile operations.

## **PART VI -APPENDIX**

### **VI.1 References**

Some of the material in this document has been gathered from the following list of references. Also, this bibliography represents good sources for additional ideas or more details.

- Ahel, M., et. al., "Behaviour of Nonionic Surfactants in Biological Waste Water Treatment."
- Ahel, Marijan and Giger, Walter, "Determination of Alkylphenols and Alkylphenol Mono- and Diethoxylates in Environmental Samples By High-Performance Liquid Chromatography."
- Ahel, Marijan, et. al., "Persistent Organic Chemicals in Sewage Effluents. 3. "Determinations of Nonylphenoxy Carboxylic Acids by High-Resolution Gas Chromatography/Mass Spectrometry and High-Performance Liquid Chromatography."
- Ahel, Marijan and Giger, Walter, "Determination of Nonionic Surfactants of the Alkylphenol Polyethoxylate Type by High-Performance Liquid Chromatography."
- Bergenthal, J., et al., "Dyebath Reuse Tests Verify Quick Payback," Textile World, September 1983.
- Bergenthal, J., et al., "The Case for Direct Dyebath Reuse," Carpet and Rug Industry, October 1984.
- Carr, W., and Cook, F., "Savings in Dyebath Reuse Depend on Variations in Impurity Concentrations," Textile, May 1980.
- Conway, Richard A. and Waggy, Gene T., "Biodegradability Testing of Typical Surfactants in Industrial Usage."
- Cook, F., and Tincher, W., "Dyebath Reuse in Batch Dyeing," Textile Chemists and C & C January 1978.
- Cook, F., "Direct Dyebath Reuse: The Future is Now!" Textile World, September 1983.
- Cook, F., et al., "Plant Trials on Dyebath Reuse Show Savings in Energy, Water, Dyes and Chemicals," Textile Chemists and Colorist & January 1980.
- Cosgrove, W. J., "Water Pollution and the Textile Industry," Canadian Textile Journal, January 1970.
- Czuczwa, et. al., "Determination of Trace Levels of Phenol and Cresols in Rain By Continuous Liquid-Liquid Extraction and High-Performance Liquid Chromatography."
- Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills, US. EPA, Document EPA 440/1-79/0226, October 1979.
- "Dyeing Cotton, Cotton Blends for Circular Knitted Fabric," Robbie L. Stone, Kinning Times May 1, 1978, Vol. 47, No. 19.
- Eckenfelder, W. Wesley, Jr., Water for Practicing Engineers, Barnes & Nobles, New York, 1970.



- Fair, Gordon Maskow and Geyer, John Charles, Water and Waste Water, John Wiley & Sons, Inc., New York, 1954.
- Gardener, Deirde and Borne, B. J., "Textile Waste Waters: Treatment and Environmental Effects," JDSC, August 1978.
- Handbook of Environment Control, Chemical Rubber Publishing Company, Section 2.6 (Textiles).
- Giger, Walter, et. al., "Persistent Organic Chemicals in Sewage Effluents: 1. Identifications of Nonylphenols and Nonylphenoethoxylates By Glass Capillary Gas Chromatography/Mass Spectrometry."
- Huisingh, Donald, Hilger, Helene, Thesen, Sven, and Martin, Larry, "Profits of Pollution Prevention" - A Compendium of North Carolina Case Studies, North Carolina Department of Natural Resources and Community Development, May 1985.
- Hunt, Robert G. and Metzler, Suzanne Chestnut, Draft. Final Report - Industrial Resource Recovery Practices: Textile Mill Products Industries, U.S. Environmental Protection Agency, June 1982.
- Hunt., G., "Dyebath and Bleach Bath Reconstitution for Textile Mills," Pollution Prevention Pays Tips, North Carolina Department of Natural Resources, Raleigh, NC, 1985.
- "Improved Dyeing System Reduces Energy, Chemical and Labor Requirements for 100% Cotton and Natural Blend Knit Fabrics," Cotton Incorporated News Bulletin, May 1, 1977.
- Jones, E. L., Alspaugh, T. A., and Stokes, H. B., "Aerobic Treatment of Mill Wastes."
- Keefer, C. E., Sewage Treatment Works, McGraw-Hill, New York, 1940.**
- McEvoy, James and Giger, Walter, "Determination of Linear Alkylbenzenesulfonates in Sewage Sludge by High-Resolution Gas Chromatography/Mass Spectrometry."
- Marcomini, Antonio and Giger, Walter, "Simultaneous Determination of Linear Alkylbenzenesulfonates, Alkylphenol Polyethoxylates, and Nonylphenol By High-Performance Liquid Chromatography."
- Moore, Sam, et. al., "Aquatic Toxicities of Textile Surfactants", Text., Vol. 19, No. 5, May, 1987.
- Nemerow, N. L., Theories and Practices of Industrial Waste Treatment, Addison-Wesley, Reading, Mass., 1963.
- NITS Document BP84206473, U.S. Department of Commerce, Washington, D.C., May 1984.
- NITS Document PB84206465, U.S. Department of Commerce, Washington, D.C., May 1984.
- "Open Width Pad/Batch Dyeing of Cotton Fabrics," Cotton Incorporated Technical Bulletin, TCR 207, December 1978.
- Petty, J., "Low Energy Dyeing of Type 6 Nylon Carpet Yarn," American Dyestuff Reporter, June 1981.
- Pollution Prevention Bibliography, North Carolina Department of Natural Resources and Community Development, January 1986.

- Porter, John J. and Sinder, Eric H., "Long-term Biodegradability of Textile Chemicals," Journal WPCF, Vol. 48, No. 9, September 1976.
- Queen, L., "Size Recovery Using Ultrafiltration Membranes," Textile Industries, August 1981.
- Rubey, Robert G., "Wastewater Heat Recovery," Midwinter Conference on Textile Wastewater Treatment and Air Pollution Control, Hilton Head Island, South Carolina, January 1982.
- "Russell's Condensate System Saves \$1,000/day," Textile World, June 1986.
- Schlesinger, Herbert A., Dul, Emil F., and Fridy, Thomas A., Jr., Chapter 15, "Pollution Control in Textile Mills."
- Smith, Brent, "Determining Optimum Wet Pickup Levels in Low Add-On Finishing," American Dyestuff Reporter, May 1985.
- Smith, Brent, "Identification and Reduction of Pollution Sources in Textile Wet Processing," Pollution Prevention Pays Program, NC Division of Environmental Management, 1986.
- Smith, C. Brent, "Solid Waste Disposal - A Case History," Textile Wastewater Treatment and Air Pollution Control Conference, Hilton Head Island, South Carolina, February 1981.
- Stafford, William, and Northup, Harold J., "The BOD of Textile Chemicals," American Dyestuff Reporter, May 23, 1955.
- Stephanou, Eripides and Giger, Walter, Persistent Organic Chemicals in Sewage Effluents: 2. Quantitative Determinations of Nonylphenols and Nonylphenol Ethoxylates by Glass Capillary Gas Chromatography."
- Stewart, James M., Aquatic Bioassay Toxicological Summary, January 15, 1986 (available from WRII).
- Stone, Rob L., "A Conservative Approach to Dyeing Cotton," Cotton Incorporated, May 1979.
- Sucheki, Stanley M., "Troubleshooting in the Dyehouse," Textile Industries, December 1977.
- Tedder, Steve W., Aquatic Bioassay Toxicological Summary, March 31, 1986, unpublished (available from NCDEM).
- "The BOD of Textile Chemicals," Updated List - 1966, American Dyestuff Reporter, August 29, 1966.
- "The Cost of Clean Water," Volume III, No. 4, Textile Mill Products, U.S. Department of the Interior, June 1967.
- "The Effect of Textile Dyeing Effluents on the Environment," Chapter 9, ADMJ-EPA Sponsored Study.
- Tincher, W., Energy Conservation in Carpet Dyeing by Dyebath Recycling," American Dyestuff Reporter, May 1977.
- Tincher, W., et al., "Reusing Dyebaths in Jet Dyeing," Textile Chemist and Colorist, December 1981.
- Veith, G.D., and Kiwis, L.M., "Exhaustive Steam-Distillation and Solvent-Extraction Unit For Pesticides and Industrial Chemicals."

**VL2 Index**

Acid . . . . .	46
Acylic . . . . .	5
Alkali . . . . .	46
Alkalinity . . . . .	40
Ammonia Mercerization . . . . .	40
Anionic Surfactants . . . . .	12-13
Aquatic Toxicity . . . . .	6,13ff
Artificial Inteliigence . . . . .	55
Audit Procedures. . . . .	47-48
Automated Chemical Systems . . . . .	54-55
Beck Audit.....	50
Beck Operation . . . . .	51
Bibliography . . . . .	61-63
Biocides . . . . .	.10-11
Bleaching Equipment . . . . .	16,52-53
BOD . . . . .	6,38-40
Carpet Dyeing . . . . .	36
Case Histories:	
Cleaning Solvents . . . . .	56
Dyebath Reuse . . . . .	23,27,31
Heat (Energy) . . . . .	37.58
Heat Transfer Fluid Recovey . . . . .	57
Isopropyl alcohol . . . . .	58
Metals . . . . .	9-10
Phosphates . . . . .	57
Printing Inks . . . . .	56
Raw Material Control . . . . .	44
Solvents (Laboratory) . . . . .	57
Surfactants . . . . .	14
Cationic Surfactants . . . . .	13
Caustic Recovery . . . . .	40
Chemical Audit . . . . .	47-48
Chemical Commodities . . . . .	45-47
Chemical Consemation . . . . .	3
Chemical Evaluation . . . . .	41-42
Chemical Prescreening . . . . .	42-43
Chemical Specialties . . . . .	12,41-42
Chemical Substitution . . . . .	3, 8ff, 11-13
Chlorinated Solvents . . . . .	14-15
CMC Size . . . . .	38
Coating (Foam) Operations . . . . .	36
COD . . . . .	6.14
<b>Coning Oils</b> . . . . .	<b>12</b>
Controllers . . . . .	54
Color . . . . .	3.5.34
C o t t o n D y e i n g . . . . .	3
Counter Current Washing . . . . .	16
D D B S A , . . . . .	12
Desiring . . . . .	19

Dye &St	32-33
Dye Dispensing Systems	54-55
Dye Fixation	5,34
Dyebath Reuse	19-21
Dyebath Analysis	20-21
Dyes	3,9,21-22,32
Dyeing,Cotton	3
Dyeing Machines	18,55
Dyeing, Water Consumption	18
Economic Benefits (see case histories)	2,20-22,32-33,43
Equipment	52-55
Equipment Audit	49-50
Ethoxylate Surfactants	12
Expert Systems	54-55
Extraction Equipment	53
Fiber Reactive Dyeing	31ff
Foam Processing	59ff
Hazardous Waste	1,6
Heat Recovery	37
Herbicides	10-11
HLB	13
Horizontal Water	16-18
Housekeeping	4,49
Inclined Washer (see Horizontal Washer)	
Knitting Oil	6,12,47
Lab to Production Correlation	34
Liquor Ratio	18,34
Linear alcohol surfactants	12
Lint Removal	5
Maintenance	4,49-51
Maintenance Chemicals	4,6,15
MassBalance	47
Mechanical Audit	49-51
Metals..	3,5,6,8ff
Mercerization	; 40
Microprocessor Controllers	54
Naphthaline sulfonic acid surfactant	12
Noncontact Cooling Water	16
Nonionic Surfactants	12
Nonprocess Sources..	4,6,15.48
Nonyl phenol ethoxylate	12
Oxyditing Agents	46
Package Dyeing	54
Pad Batch Dyeing	31ff
Phenols..	5
Phosphates	5,11
Photographic Processing	11
Print Paste	5
Printing	5
Process Modification	4, 16ff
Process Optimization	3
PVA Size	38

Raw Material Control	3,42-43
Reducing Agents	47
Reduction Strategies (general)	1
Reduction Techniques	2-4
Recycle (see Reuse)	
Reuse	4
S a l t	4 5
Scouring	19
Segregation	4, 15
Shade Repeats	34
Sodium lauryl sulfate	12
Solvent substitutions	15
Solvents	4ff, 14
Source Reduction, Concept	2
Spin Finishes	12
Starch size	38
Substitutions:	
Dyes	9-10
M e t a l s	8 - 1 1
Phosphates	.. 11
Solvent	14-15
Sulfated ethoxylate surfactants	12
Sulfonic acid surfactants	13
Surfactant Toxicities	13-14
Surfactant Treatability	13-14
Surfactant Types	12-13
Surfactants	5,6,12K
Tallow amine surfactants	13
Titration	.
Toxic Waste	1,6
Vacuum Extraction Equipment	53
Warp Size	6,12,19,47
Warp Size Recovery	38-40
Washers	..16-19
Waste, Classification	1
Waste, Dispersable	1,5
Waste, Hard to treat	1.5
Waste, Hazardous	1,5
Waste, High Volume	1,6,45
Waste Recovery (see also Reuse)	37ff
Waste,Toxic	1
W a s t e	1 , 5
Water Conservation	16H
Winding Emulsion	12

### VI.3 Glossary

For a complete glossary of textile terms, see “Man-Made Fiber and Textile Dictionary” published by Celanese Corporation, 1211 Avenue of the Americas, New York, NY 10036 (212-764-7640) or P.O. Box 32414, Charlotte, NC 28232 (704-554-2000).

A Frame	Device for supporting rolls of fabric so they can rotate freely during wet processing
AATCC	American Association of Textile Chemists and Colorists, Box 12215, Research Triangle Park, NC 27617
ADBAC	Alkyl Dimethyl Benzyl Ammonium Chloride surfactant, similar to commercial BTMAC
AP	Nonyl - or octylphenoethoxylate surfactant
Bicard	Sodium Bicarbonate
Bleach	Calcium hypochlorite, 30% solution in water
BOD	Biological Oxygen Demand - The amount of oxygen required for biodegradation of a chemical substance in a standard test, usually expressed in parts per million
BTU	British Thermal Unit: The amount of heat required to increase the temperature of one pound of water by one degree Fahrenheit
Carrier	A chemical dyeing accelerant for disperse dyes on polyester
Caustic	A 50% solution of sodium hydroxide in water
CI	Color Index, a list of chemical formulae and properties of dyestuffs available through AATCC
CMC	Carboxymethyl cellulose warp size
COD	Chemical Oxygen Demand - The amount of oxidizer consumed during oxidation of a chemical substance by dichromate in a standard test, usually expressed in parts per million
DDBSA	Dodecyl Benzene Sulfonic Acid
DEC	Diethanol cocoamide surfactant
DTPA	Diethylene triamine pentaacetic acid
EDTA	Ethylenediaminetetraacetic acid (tetrasodium salt)
EPROM	Erasable Programmable Read Only Memory for microprocessor controllers
GL Salt	Sodium sulfate (may be hydrated)
GPD	Gallons per minute
<b>HLB</b>	Hydrophilic/lipophilic balance of a surfactant

Hydro	Sodium hydrosulfite powder
<b>ITMA</b>	International Textile Machinery Show, Paris, France, October, 1987
JBox	A certain configuration of continuous bleaching kier
L	Liquor to goods ratio: The weight of the treating solution divided by the weight of the goods being processed
<b>LAE</b>	Linear alcohol ethoxylate surfactant
<b>LC50</b>	Chemical concentration which is lethal to 50% of the specimens treated in a standard test. Note: Higher values of LC50% represent lower toxicities
LP	Liquified Petroleum gas
MSP	Monosodium phosphate
NCDEM	North Carolina Division of Environmental Management, Archdale Building, Raleigh, NC 27611
NSA	Naphthaline sulfonic acid surfactant (dispersant)
P	Phosphorous
PAA	Polyacrylic acid warp size
PET	Polyethylene terephthalate (polyester)
PH	A measure of acidity/alkalinity: pH is the negative logarithm of hydrogen ion concentration in an aqueous solution
POT-W	Publicly Owned Treatment Works: Generally this refers to municipal wastewater treatment systems
PPm	Parts per million, a unit of mass/mass concentration: one percent is 10000 ppm
PPP	Pollution Prevention Pays Program, Division of the Office of Waste Reduction, Barrett Drive, Raleigh 27609
PVAc	Polyvinyl acetate warp size: Sometimes called PVA
PVOH	Polyvinyl alcohol: Sometimes called PVA
Resin	Any compound capable of either crosslinking with cellulose or self crosslinking, especially a bis(N-methylol) compound
Salt	Sodium Chloride
SEA	Sulfated alcohol surfactant
SLS	Sodium lauryl sulfate surfactant

Soda Ash	Sodium carbonate
----- be aln	A formulated (usually proprietary) textile wet processing chemical <b>mixture</b>
TAE	Tallow amine surfactant
TDS	Total dissolved solids in a water sample, usually expressed in parts per million
TSP	Trisodium Phosphate
--	Total suspended solids in a water sample, usually expressed in parts per million
TSPP	Tetrasodium polyphosphate
VOC	Volatile organic compound (air pollutant)
WRRI	Water Resources Research Institute, NC State University, Raleigh, NC 27696